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VIRGINIA GEOLOGICAL SURVEY

UNIVERSITY OF VIRGINIA

THOMAS LEONARD WATSON, PH. D.

DIRECTOR

Bulletin No. XII

The Coal Resources of the
Clintwood and Bucu
Quadrangles,
Virginia

BY

HENRY HINDS

PREPARED IN COÖPERATION WITH THE
UNITED STATES GEOLOGICAL SURVEY

CHARLOTTESVILLE
UNIVERSITY OF VIRGINIA

1916

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LETTER OF TRANSMITTAL

VIRGINIA GEOLOGICAL SURVEY,
UNIVERSITY OF VIRGINIA,

CHARLOTTESVILLE, July 15, 1916.

Governor Henry C. Stuart, Chairman, and Members of the State Geological Commission:

Gentlemen:—I have the honor to transmit to you herewith, and to recommend for publication as Bulletin No. XII of the Virginia Geological Survey Series of Reports, a manuscript and illustrations of a report on "The Coal Resources of the Clintwood and Bucu Quadrangles, Virginia," by Mr. Henry Hinds.

This report has been prepared by the Virginia Geological Survey in coöperation with the U. S. Geological Survey, and is the second one of a series to be published under the coöperative agreement of the State and Federal Surveys on the coals in southwest Virginia. It embodies a study of the coals in those parts of Dickenson, Buchanan, and Russell counties included in the Clintwood and Bucu quadrangles, and should prove of much economic value in directing attention to an important area possessing in quantity bituminous coals of great purity and value.

Respectfully submitted,

THOMAS L. WATSON,

Director.

THE COAL RESOURCES OF THE CLINTWOOD AND BUCU QUADRANGLES, VIRGINIA

BY HENRY HINDS.

INTRODUCTION

Location and importance of the area.—The Clintwood and Bucu quadrangles are almost entirely in southwest Virginia (see fig. 1), chiefly in Dickenson, Buchanan, and Russell counties. A small area in the southwest corner of the Clintwood quadrangle is in Wise County and a few square

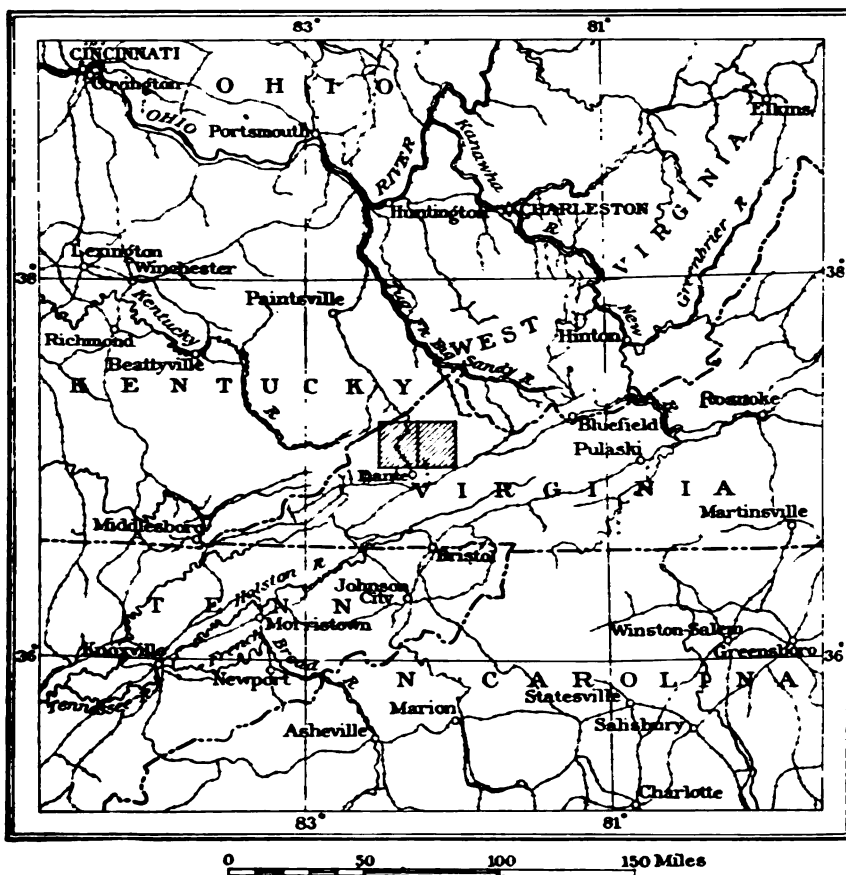


Fig. 1.—Index map showing the location of the Clintwood and Bucu quadrangles.

miles in the northwest corner are in Pike County, Kentucky. These quadrangles form the south half of the old Grundy 30-minute quadrangle and contain 476 square miles.

The quadrangles lie on the southeast border of the central part of the Appalachian coal field and contain large quantities of untouched coal. As will be shown, there are in the ground in beds 14 inches and more in thickness, about 10,367,000,000 tons of high-grade, coking bituminous coal. Because of their former inaccessibility the coal resources of most of the region have not yet been utilized, but the recent construction of the Carolina, Clinchfield & Ohio Railway extension from Dante, Va., to Elkhorn City, Ky., has furnished communication with both the South and the Middle West for a large area. The near future should bring the installation of large mining plants, the building of busy coal camps, and the shipping of great quantities of valuable fuel to other parts of the country. A start in this direction has already been made in the southern part of the quadrangles, in an area which has been relatively more accessible.

The survey upon which this report is based was undertaken primarily because of the great potential value of the coal resources of the region and the lack of knowledge concerning them, even among the inhabitants of the area. This report is preliminary and is issued in advance of the preparation of engraved geologic maps in order to meet demands for immediate information. It is planned to include in a later report engraved maps, showing geologic formations and structure, coal outcrops, topography, drainage, and culture on the same sheet.

Method of work.—The northwest corner of the Clintwood quadrangle, including the Kentucky area on the north and Georges Fork and Brush Creek on the south, was surveyed geologically by Charles Butts in 1912. The rest of the region was surveyed in 1913 and 1914 by T. K. Harnsberger and the author, with the help of C. M. Bauer for six weeks, and of C. A. Davidson for a few days. Mr. Harnsberger assisted in the office during nearly all the preparation of this report. The expense of the undertaking was shared by the United States Geological Survey and the Virginia Geological Survey, the former organization being represented by Mr. Butts and the author, and the latter by Messrs. Harnsberger, Bauer, and Davidson. David White, Chief Geologist of the United States Geological Survey, had general supervision of the work, and added materially to its value by his identifications of fossil plants and critical examination of coal analyses.

The geologic survey was made at the same time as a detailed topographic survey in charge of J. I. Gayetty, and the topographic corps rendered

valuable aid in determining the location and elevation of a number of coal openings and exposures. By this method the geologists had available many more instrumentally determined elevations than appear on the printed maps, but were handicapped in making locations by the lack of completed and adjusted topographic sketching. Geologic profiles were made of all roads and paths and all reported coal openings were visited, but it was soon seen that the lack of well-defined stratigraphic markers, the heavily timbered condition of the country, the rarity of natural coal exposures, and structural irregularities made additional work necessary. Sections 400 to 800 feet long were, therefore, measured at intervals of half a mile to a mile along all the principal valleys. The elevations of the principal exposures were usually read both in going up and coming down, and the barometer was frequently checked at stadia stations to correct errors arising from variations in atmospheric pressure. It may be confidently asserted that the work was more detailed than any other that has been conducted by public geological surveys in the coal fields of the Appalachian region.

Acknowledgments.—The writer is greatly indebted to W. D. Tyler, of the Clinchfield Coal Corporation, for records of many diamond-drill holes (Pls. II and III), maps of accurate transit surveys of coal outcrops, and measurements of coal beds in hundreds of prospect pits. These data were available for the most important parts of the Russell Fork drainage basin, and for nearly all of the Clinch River drainage basin except the Lewis Creek area. Outcrop maps and coal measurements, chiefly in the Levisa Fork drainage basin, were furnished by E. V. d'Invilliers and J. B. Dilworth, and by Charles Catlett.

The only publication describing the geology and coal resources of the quadrangles is the result of a hurried reconnaissance survey by R. W. Stone in the Russell Fork area,¹ and this has been drawn upon for several coal measurements. The Tazewell and Bristol folios of the U. S. Geological Survey, by M. R. Campbell, describing adjacent quadrangles on the east and south, respectively, and recent reports by Charles Butts on the Pound quadrangle² were of material assistance.

¹ Stone, R. W., Coal resources of the Russell Fork basin in Kentucky and Virginia: U. S. Geol. Survey Bull. 348, 1908.

² Butts, Charles, The coal resources and general geology of the Pound quadrangle in Virginia: Va. Geol. Survey Bull. IX, 1914.

The coal resources and general geology of the Pound quadrangle in Virginia and Kentucky: U. S. Geol. Survey Bull. 541, 1914.

GEOGRAPHY

TOPOGRAPHIC FEATURES.

Relief.—The surface of the country is decidedly hilly and is mountainous in some respects. Flat lands even a few acres in extent are rare and valley slopes, though not precipitous, are very steep nearly everywhere. The entire region is thoroughly dissected by streams, the principal water courses being only a few miles apart and separated by ridges that rise 500 to 1,000 feet above them. Except in parts of the southeastern corner of the Bucu quadrangle, which is outside the coal field and need not be considered here, the valleys are deep, narrow, and V-shaped, with little or no flat bottom lands. Some valleys, notably those of Russell Fork and Fryingpan Creek, are remarkably straight for long distances; others, notably those of Pound and Cranesnest rivers, are winding, so that water in the streams travels long distances between points not far apart. The ridges are steep sided, winding, and very irregular in horizontal outline, with many side spurs. Most of the few small flat areas in the region are on the divides, but by far the greater part of the ridge tops are very narrow. The heights of neighboring ridges are approximately the same in most districts.

The maximum relief of the quadrangles is 2,665 feet, the lowest point being on Levisa Fork, with an elevation of 1,070 feet above sea-level, and the highest on Big A Mountain, with an elevation of 3,735 feet. The most conspicuous topographic features are Big A Mountain and Pine Mountain, locally known as "Cumberland Mountain." Big A is an exceptionally high part of Sandy Ridge about $2\frac{1}{2}$ miles long and bearing several knobs. Pine Mountain is a long, nearly straight ridge with a serrated sky-line. It extends from Russell Fork on the northeast into Tennessee on the southwest. The highest point on it in the Clintwood quadrangle has an elevation of 3,137 feet. The southern slopes of the mountain are long and comparatively gentle, but the northern slopes are very steep and descend a vertical distance of nearly 2,000 feet in a distance of less than $1\frac{1}{2}$ miles between the mountain crest and Elkhorn Creek, in Kentucky.

There are several other ridges that deserve special mention. Sandy Ridge is a conspicuous feature that forms the divide on the north side of the Clinch River drainage basin. It is nearly as high as Pine Mountain and winds irregularly across the Bucu quadrangle, merging with Big A Mountain. It enters the Clintwood quadrangle only near the head of



(A) View of Pine Mountain from ridge near the mouth of Pound River.



(B) View of Russell Fork valley from Council. with northeast end of Big A Mountain in distance.

McClure River, but lies only a short distance south of the boundary elsewhere. Big Ridge extends from Sandy Ridge northeastward to the mouth of Pound River, forming the divide between Cranesnest and McClure rivers. Fletcher Ridge is the divide on the southwest side of the Garden Creek drainage basin, extending from Sandy Ridge northwestward to join Winding Ridge. A dome-shaped knob on Fletcher Ridge, 3 miles north of Council, can be seen for many miles.

Drainage.—The streams of the quadrangles are tributary to two great drainage systems. Those on the south side of Sandy Ridge flow into Clinch River, which joins the Tennessee, a river that flows as far south as Alabama and then turns west and north to the Ohio. Streams north of Sandy Ridge are tributary to either Russell or Levisa forks of the Big Sandy River and reach the Ohio by a direct northerly route. The largest tributaries of Russell Fork are Pound, Cranesnest, and McClure rivers, and those of Levisa Fork are Dismal, Garden, and Prater creeks. Only the upper parts of moderately large creeks belonging to the Clinch River drainage system are included in the quadrangles.

Although even small tributaries contain some running water during most of the year, none of the streams have a very large flow. Even row boats have trouble in navigating Russell and Levisa forks, the largest streams, for any considerable distance, and bridges are considered a luxury rather than a necessity. Logs are floated down the Levisa to a small extent, and a large number of them are sent down the lower part of Russell Fork by means of a splash dam just north of the mouth of Pound River. The rainfall of the region is exceptionally great, but the sandy soil, dense growth of trees and brush, and high stream gradients prevent floods. According to common usage in this region, the "right" and "left" sides or forks of a stream are considered relative to the position of a person facing upstream.

INDUSTRIAL FEATURES.

Settlement.—The original settlers subsisted chiefly by hunting, but now squirrels and a few rabbits and birds are practically the only wild game. Corn, raised in small cleared patches on steep slopes, a little garden truck, and hogs that are allowed to run wild during most of the year are the chief, and almost the only, farm products. Except in the growing coal mining camp at Wilder, about the only occupations of the people are farming and lumbering. The largest towns are Clintwood, the Dickenson County seat, with a population of about 350, and Wilder. The population

of both quadrangles is roughly estimated at 11,000 or 12,000 people. Negroes are not at present encouraged to enter the territory north of Sandy Ridge.

Accessibility.—The area south of Sandy Ridge has had easy access to the outside world since the construction of the Clinch River division of the Norfolk and Western Railway many years ago. The area north of Sandy Ridge, however, has been more or less isolated by Sandy Ridge on the south and Pine Mountain on the north, as well as by the hilly character of the entire region. The completion in 1915 of the extension of the Carolina, Clinchfield, and Ohio Railway, under Sandy Ridge and down McClure River and Russell Fork, has opened rail communication both to the south and to the north. The logging railroad of the Honaker Lumber Company carries some freight between Indian and Putnam, a station on the Norfolk and Western.

Wagon roads are rocky and very steep in places, and the usual method of travel is on horseback. Recently, however, an excellent road with low grades has been constructed from Clintwood southwestward to Darwin and Wise, and southeastward across Bearpen Gap to McClure River. Many of the ridge roads are fairly good, but wind so much that they are commonly less direct than the valley roads. There are few ridge roads in the north half of the Bucu quadrangle.

Present and future coal production and markets.—Until a few years ago the only coal mined in the quadrangles was taken from small country mines for use in the immediate neighborhood. Recently mine 2 of the Clinchfield Coal Corporation at Dante and the Cranesnest mine of the same company near Toms Creek have been driven through Sandy Ridge, and considerable coal is being taken from under lands on the southern border of the Clintwood quadrangle. The same company is also operating two large mines at Wilder, in the southwestern part of the Bucu quadrangle, and a slope mine that, though south of the quadrangle, has a main entry driven to within a few hundred feet of it. These mines are now producing much coal and have an even greater capacity. They are equipped with electric haulage and are under scientific management that considers the future as well as the present.

Present production is, however, very small when compared with that which would be justified by the coal resources of the region, and it is confidently expected that much more mining will be begun in the near future. The new railroad has opened new fields to development, and advantage of that fact will probably be taken soon. Expansion of the

industry, outside districts now active, will probably begin by the mining of the Upper Banner bed along Squirrel Camp Branch, Mill Creek, and neighboring parts of McClure River. The thick deposits in the Clintwood bed southwest of Clintwood can be reached by a railroad from McClure River under Bearpen Gap and up Cranesnest River, or one from the Toms Creek field down the Cranesnest, with a long tunnel under Sandy Ridge. Coals along the upper part of Russell Fork and along Indian and Fryingspan creeks can be hauled out over a railroad down Russell Fork to the mouth of McClure River, though it is probable that most deposits near Sandy Ridge will be reached by mines entering on the south side of that divide. To obtain rail communication for the Levisa Fork drainage basin, it would be necessary to build a rather long line, possibly involving tunneling under Sandy or other ridges, but there are several feasible routes.

Mining conditions are good. The coal beds are only gently inclined so that electric haulage may be employed, and advantage may usually be taken of the dip in order to secure natural drainage. Most of the coal beds lie above the levels of the principal streams, and may be entered by drifts. Gas is not likely to be troublesome. The underclays of the coal bed are commonly so hard and sandy that heaving and squeezing will not be common in mine workings, and the mine roofs will be of kinds of rock that are not particularly hard to support. The supply of mine timber is notably abundant, and water for power plants and camps can be obtained with little trouble.

The natural market for most of this region is the southeastern States, with their growing industrial centers. The C. C. & O. Ry. also offers direct rail communication with Charleston, where huge new coal-loading docks have been constructed with the expectation that this city will become a great shipping point for coal exported to Central and South America, especially through the Panama Canal. Ships destined for those points save more than a day by loading at Charleston instead of the principal coal ports farther north. Another market is now available through direct rail communication over the C. C. & O. and the C. & O railways with the Ohio Valley and the Middle West, but in this direction the competition of other fields with shorter hauls must be met. Shipments to the East and to the seaboard via N. & W. Ry. meet competition with high-grade coals that have shorter hauls. Mention of the relative quality of this coal and its probable competitors is made in another part of this report.

GENERAL GEOLOGY

STRATIGRAPHY.

General statement.

The rocks exposed in the Clintwood quadrangle, exclusive of residual soils and small alluvial deposits in the bottoms of the valleys, belong to the Devonian and Carboniferous systems. The Upper Devonian underlies the Carboniferous, and comes to the surface only on the northwest escarpment of Pine Mountain in Kentucky, where it consists of about 800 feet of dark to black shale, the upper part of which may be of Carboniferous age. The Carboniferous system is divided into the Mississippian series below and the Pennsylvanian series above, and each of these series, which are unconformable, is made up of a number of formations that are described below. Although a little coal has been found in the Mississippian, the Pennsylvanian contains all the minable coal beds of this region.

The indurated rocks exposed in the Bucu quadrangle include those in the systems outcropping in the Clintwood quadrangle, and also older rocks belonging to the Cambrian, Ordovician, Silurian, and Devonian systems. The pre-Pennsylvanian formations of the Bucu quadrangle, however, are intricately folded and faulted, and have been thrust up from the southeast over the younger rocks. A description of their character and distribution would have no bearing upon the coal resources of the area, and is reserved for a later geologic report.

Mississippian series.

The Mississippian series of this region consists of at least the upper part of the Grainger shale at the base, the Newman limestone near the middle, and the Pennington shale at the top. The series is exposed on the northwest slope of Pine Mountain in the Clintwood quadrangle, and in a small area in the southeastern part of the Bucu quadrangle. According to Charles Butts, the thickness of the Mississippian series along Pine Mountain is 1,700 to 1,800 feet. In the same locality the Mississippian part of the Grainger is composed chiefly of green shale and brownish sandstone with considerable red sandstone in the upper 50 feet, and is 400 to 500 feet thick. The Newman limestone is about 500 feet thick. It is oolitic and thick bedded in the lower half, but thinner bedded and containing only

a few oolitic layers in the upper half. The Pennington shale is about 800 feet thick, and is composed of red, green, and drab shale, thin-bedded, fine-grained green sandstone, and one persistent stratum of resistant siliceous sandstone 100 feet thick. Most of the Pennington was penetrated by drill hole S 1 on Cranesnest River (Pl. II).

In the southeastern part of the Bucu quadrangle the Mississippian part of the Grainger is chiefly shale. Only the lower part of the Newman is exposed, and it is thick-bedded, very fine-grained limestone. The Pennington is much thicker than on Pine Mountain, and contains several well-cemented beds of coarse sandstone. Both in this district and on Pine Mountain much of the Pennington resembles lithologically most of the Pennsylvanian series, and the lower formation is distinguished chiefly by certain beds of red or green hues—colors that are very uncommon in the commercially coal-bearing rocks.

Pennsylvanian series.

GENERAL STATEMENT.

The Pennsylvanian series, in which are all the commercially important coal beds of this area, consists of sandstone, shale, coal, and thin beds of clay. The only limestone is in small nodules at a very few horizons. These rocks, which are all of Pottsville age, were divided by Campbell in his reports on the Big Stone Gap coal field into the following formations, named in ascending order: Lee formation, Norton formation, Gladeville sandstone, and Wise formation. These formations can not be differentiated from one another by any lithologic or stratigraphic peculiarities that have wide application. No formation contains any type of bed that is not present in one or more of the others, and no member exhibits the same thickness or exactly the same lithologic character in all localities. The intervals between coal or other horizons are different in different parts of the field, so that the members of a measured section can rarely be certainly identified by comparing it with a known section 5 miles or more distant. In spite of these facts, however, and difficulties due to the thick brush and timber, the more or less omnipresent residual soil, and the local irregularities in dips, it is possible to accurately ascertain stratigraphic relations by careful tracing of a number of beds from place to place.

Sandstone constitutes one-third to nearly one-half of the Pennsylvanian rocks. It includes considerable fine-grained and thin-bedded material that has the appearance of sandy shale in weathered exposures. The most

persistent sandstone beds are thick-bedded and coarse-grained and form cliffs and benches on the valley sides. By far the greater part are buff or brownish and arkosic, stained with iron oxide and containing decomposed feldspars, mica, and other minerals, as well as the much more abundant quartz grains. Other beds, especially some in the lower part of the series, are gray and contain a large proportion of quartz grains that are firmly held together by siliceous cement. Another type of sandstone that is not very common and is confined to horizons above the Norton formation is almost pure white, fine-grained, and very resistant to weathering.

Sandstones containing rounded quartz pebbles an inch or less in diameter are common in the Lee and Norton but not in higher formations. The Gladeville contains pebbles at a few localities. This conglomeratic phase is not persistent in any of the beds, though more common in the Lee and lower half of the Norton than elsewhere.

Most of the shales are very sandy and grade into sandstone. Drab is the most common shade, though fresh exposures of several beds, especially among the lower rocks, are distinctly blue. Some of the more argillaceous shales are yellowish, and thin beds, commonly those within a few feet of coal beds, are black.

The coal beds will be discussed later. The clay beds are usually associated with coal, either as very thin partings between coal layers or as the stratum upon which the coal rests. The underclays are a few inches to a few feet thick, most of them are sandy, and many are slightly laminated, so that they resemble and grade into true shales.

LEE FORMATION.

The Lee formation, named from Lee County, Virginia, is exposed along the upper slopes of Pine Mountain, in small areas in Kentucky, near the thrust fault southwest of Big A Mountain, and low down in the valleys of Indian Creek and its principal tributaries. Only a few beds at the top of the formation are above the surface on Indian Creek, and the exact succession of strata in the other localities can not be ascertained because of steep dips, poor exposures, and heavy brush cover. A nearly complete section is exposed in The Breaks, a few miles north of the Clintwood quadrangle, one drill hole on Cranesnest River (S 1 in Pl. II) is through the entire formation, and other borings were continued into the upper part of it.

In the boring on Cranesnest River, a mile south of Darwin, the Lee is 830 feet thick, and consists largely of sandstone, conglomeratic in the

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II.

GLADEVILLE SANDST.

LEE FORMATION

lower part, with comparatively thin shales, and several coal beds. Along Pine Mountain the formation has probably about the same thickness, and the most conspicuous member is a massive sandstone, 100 to 300 feet thick, that forms the crest of Pine Mountain northeast of Blowing Rock Gap, and high points southwest of the gap that are a short distance south of the divide. This sandstone, which is at the base of the Lee, contains many smoothly rounded, white and cream-colored quartz pebbles that weather out and lie on the surface like hailstones. Like most other sandstones in the formation, this rock is grayish white and composed almost entirely of large clear quartz grains, very firmly cemented with a siliceous cement. As the dips are slightly greater than the mountain slope, successively higher beds are crossed in descending the mountain on the Virginia side. In this area the upper beds of the Lee are not well exposed, but in The Breaks the top of the formation consists chiefly of conglomeratic sandstone that is 400 to 500 feet thick and forms the lower part of the canyon walls. The only coal beds seen in the Lee of this area were two beds only a few inches thick in The Breaks.

A conglomeratic sandstone that forms a low hogback in the lower slope of Pine Mountain in Virginia and the cliff at the top of The Breaks has all the lithologic characteristics of Lee sandstones, and has been called the top of the Lee in the reports by Stone and Butts previously mentioned. The work upon which this report is based, confirmed by a study of fossil plants by David White, has shown that this bed is the bottom-rock of the Kennedy coal bed, and that its top is 400 to 550 feet above the top of the Lee.

The Lee rocks low down on the northwest side of Pine Mountain are segments of conglomerate that have been broken off and thrust upward along a fault. They dip steeply and irregularly, and probably overlies undisturbed beds in the Wise formation.

As shown by drill records (Pls. II and III), at least the upper part of the Lee contains a large proportion of sandstone and conglomerate in all of the Clintwood quadrangle about which information is available. In the southern part of the Bucu quadrangle, however, there is more shale, and the sandstones appear to be no thicker or more conglomeratic than those in the Norton formation. The exposures on Indian Creek show a coarse, thin sandstone at the top, and a 30-inch coal bed about 50 feet below the top of the formation. It is possible that the top beds of the Lee may be exposed in a very small area on Russell Fork, among the disturbed rocks between Hurricane Creek and Council, but the rocks specifically

correlated with the Lee by Stone, on Indian and Hurricane creeks and on Russell Fork, are in the lower part of the Norton.

All of the Lee is exposed southwest of Big A Mountain, where it is overturned and dips at high angles to the southeast. In this area there is a moderately thick conglomerate at or near the base of the formation, but other sandstone beds are not notably coarse-grained or siliceous, and shale constitutes a half or a third of all beds. The thickness of the Lee here is about 1,500 feet, indicating a thickening from Pine Mountain to the southeast. No coal beds more than a few inches thick were seen, though exposures are far from perfect.

NORTON FORMATION.

The Norton formation, named from Norton in Wise County, forms by far the greater part of the surface of the Clintwood and Bucu quadrangles, outcropping in most districts from the bottoms of the valleys nearly to the ridge tops. The thickness of the Norton has been obtained at many points by combining drill records (see Pls. II and III) with outcrop observations, and ranges from 920 feet in the northern part of the Clintwood quadrangle to 1,485 feet in the southern part of the Bucu quadrangle. The direction in which the greatest thickening takes place is slightly east of south, and all parts of the section are involved in the increase. This feature and the stratigraphic succession and thickness of intervals is shown by the drill records (Pls. II and III), the generalized sections (Pl. IV), and the local sections. The local intervals between coal beds are also mentioned in the detailed descriptions of each drainage basin.

The formation consists chiefly of alternating beds of sandstone and shale, with a number of coal beds, and thin layers of clay in and under some coal deposits. Small limestone nodules were found at a very few horizons. The most significant and important deposits are the coal beds, which will be described later in the section devoted to economic geology. Other beds are most readily described in connection with the coal beds with which they are associated, and that method of treatment will be adopted. Only a few facts of a general nature will be mentioned here.

The most easily identified horizon, considering the field as a whole, is that of the Kennedy coal, near the middle of the Norton. As this bed is underlain everywhere by coarse sandstone that forms ledges and cliffs, and overlain by nearly 200 feet of shale and thin-bedded, fine-grained sandstone that forms long slopes, its position is usually easy to find. Its usefulness as a stratigraphic marker is increased by the fact that the general north-

westerly dip causes it to outcrop for long distances a few hundred feet above the principal streams. Except on the eastern border of the quadrangles and locally elsewhere there is a large proportion of sandstone, and more of the coarse-grained type below the Kennedy than above it. The sandstone underlying the Kennedy is 50 to 200 feet thick and contains at least a few pebbles in parts of most districts. This conglomeratic feature is conspicuous only along Dismal Creek and at the foot of Pine Mountain, where the sandstone is gray and siliceous and forms high cliffs. The Kennedy bottom-rock of the Pine Mountain district has been called the top of the Lee in reports by both Butts and Stone. The Kennedy bottom-rock on Dismal Creek is the same as the Dismal conglomerate lentil of Campbell, described in the Tazewell folio.

Several other sandstone beds are locally conglomeratic and exceptionally coarse and form conspicuous ledges and cliffs. One of these is a gray, quartzose bed that lies between the Tiller and Jawbone coal beds along Russell Fork near Council, along parts of Indian Creek, and along Dismal Creek and Levisa Fork near Dismal Creek. This bed resembles certain sandstones in the Lee formation and has been mistaken for them. A similar bed underlies the Tiller coal bed in places. A buff, more arkosic sandstone, about 60 feet thick and with thin layers of pebbles near the base, is a useful marker in the southern part of the Bucu quadrangle and all except the northeastern part of the Clintwood quadrangle. This bed is separated from the top of the Norton by shale 60 to 100 feet thick. Near the eastern boundary of the Bucu quadrangle the interval between the top of this sandstone and the Upper Banner coal horizon is occupied chiefly by coarse, rather poorly cemented sandstone.

Many shale beds are sandy and of the types described as most common in the Pennsylvanian series. The most persistent bed is at the top of the Norton, is not very sandy, and is in part yellowish. Where traced by Hennen in Mingo and McDowell counties, West Virginia, there is a persistent marine horizon in this shale at which there are invertebrates of a type found also on Keen Mountain in the Bucu quadrangle, between Dismal Creek and Levisa Fork.

GLADEVILLE SANDSTONE.

The Gladeville sandstone was named from Gladeville, now Wise, the county seat of Wise County, where it is an important stratigraphic marker. In most parts of these quadrangles it is also a useful marker, though no better than several other beds not separately mapped. According to Butts,

who traced the bed from its type locality to the Clintwood quadrangle, it is hard, white, and siliceous at Wise, and more arkosic and thinner on the north side of Sandy Ridge. In the Clintwood and Bucu quadrangles the Gladeville is 60 to 110 feet thick, is stained brownish by iron, and contains considerable argillaceous matter, mica, and other minerals. Although coarse-grained and thick-bedded to massive, it rarely forms strong cliffs, and readily breaks up on weathering into its constituent grains. In many districts this sandstone forms the upper parts of the principal ridges and many small patches of corn thrive upon it. In the northwestern part of the area between Russell and Levisa forks the bed has its minimum thickness and is more compact than elsewhere.

WISE FORMATION.

The Wise formation, named from Wise County, Virginia, differs little in essential particulars from the Norton formation. The Wise is very thick farther west, but only the lower 575 feet are exposed in these quadrangles. Except near Clintwood, the Wise is confined to the upper parts of the ridges and occurs only in small patches in much of the region. The stratigraphic succession and thicknesses of intervals may be ascertained by consulting the generalized sections (Pl. IV), the local sections, and the detailed descriptions of each drainage basin.

The lower 200 feet of the Wise formation contains fine coal beds that will be described in the section devoted to economic geology, and a considerable proportion of sandstone. The resistant sandstone bed noted by Butts just above the Clintwood coal in the Pound quadrangle is a good marker only near Clintwood, being nonresistant or absent elsewhere. West of McClure River, the best marker is a white, firmly cemented, siliceous sandstone that, though not thick, outcrops conspicuously 15 to 60 feet above the Gladeville. The best marker in other districts is a grayish, resistant sandstone that lies between the Eagle and Clintwood coal beds and forms cliffs 100 feet or less in height. For about 200 feet above the Clintwood coal the sediments are chiefly shales, and these are succeeded by thick beds of brownish-buff, medium-grained, nonresistant sandstone, within which there is another coal bed.

Correlations with adjoining areas.

The correlations made by the writer between coal beds in southwest Virginia and the Elkhorn coal field in Kentucky differ from those previously made (see Pl. V) chiefly because early ties were necessarily made across

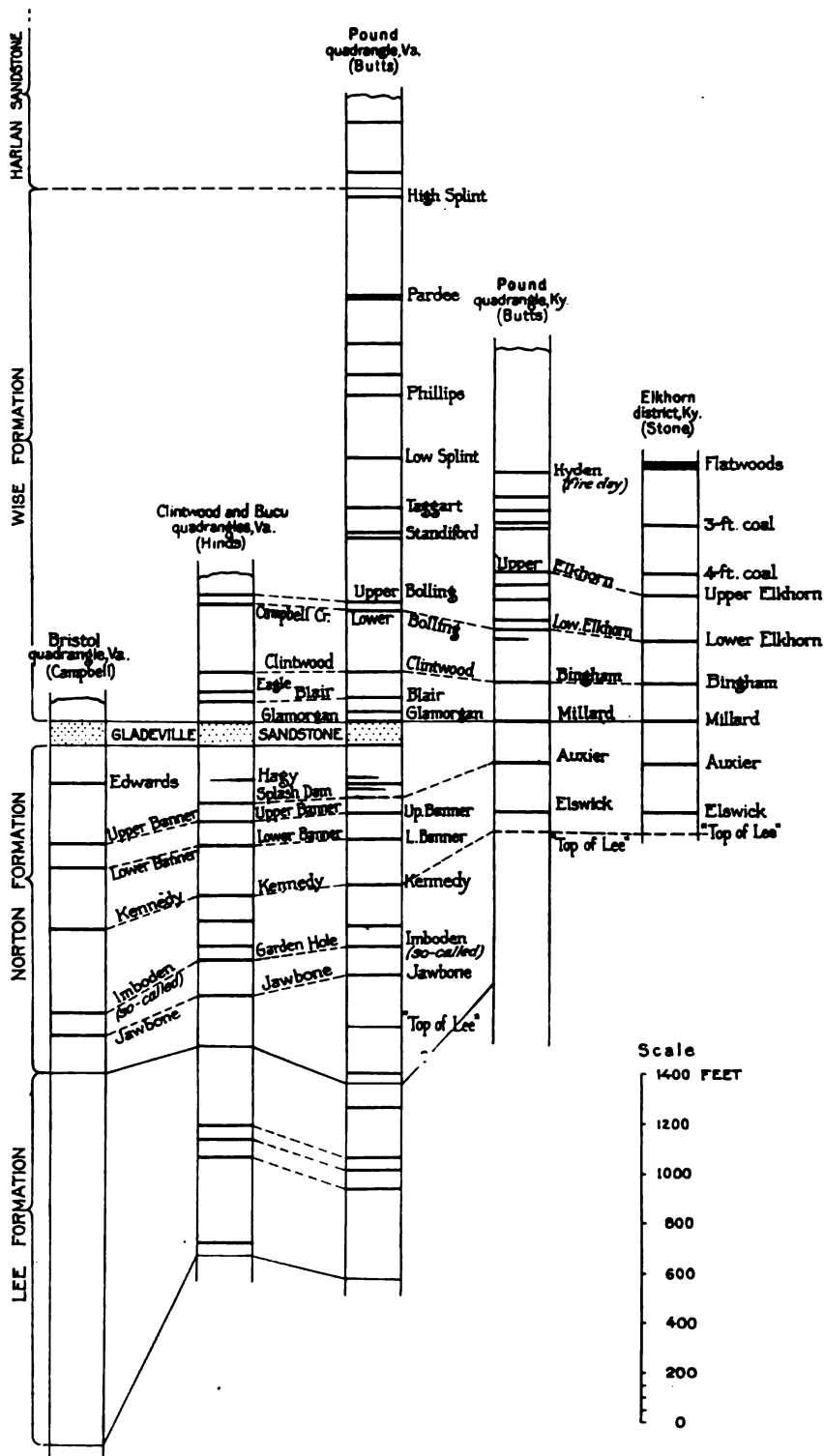


PLATE V. SECTIONS SHOWING CORRELATIONS WITH ADJOINING AREAS

the gap formed by Pine Mountain and the Pine Mountain fault, where no actual tracing of beds from one field to the other is possible. The work upon which the present report is based was continued so as to include the northern half of Buchanan County to the boundaries of Kentucky and West Virginia, and a tie line was made by the author in 1915 from Elkhorn City down Russell Fork, up Marrowbone Creek, and over the Flatwoods to Shelby Creek, where it joined detailed private surveys carried from Jenkins. The results of detailed private surveys in southeastern Pike County confirmed the conclusions reached. Correlations were also greatly strengthened by a preliminary examination of fossil plant collections by David White.

There can be no question concerning the accuracy of the identifications of the Upper and Lower Banner and Kennedy coal beds in the Clintwood and Bucu quadrangles. The position of the Jawbone coal bed and the top of the Lee formation in this area is based upon the stratigraphic intervals and somewhat meager lithologic descriptions given by Campbell for neighboring parts of the Bristol quadrangle. If the Jawbone correlation is correct the "so-called Imboden" is the equivalent of the Garden Hole coal bed. The Gladeville sandstone was traced by Butts from its type locality at Wise through the Pound quadrangle to the Clintwood. On parts of the Sandy Ridge, Campbell has apparently included in his mapping of the Gladeville a thin but conspicuous resistant white sandstone that is separated from the Gladeville of Butts by a moderately thick shale bed.

The identification of horizons above the Norton in this report agrees essentially with those made by Butts in the Virginia portion of the Pound quadrangle. His identifications of certain Norton coal beds and of the top of the Lee formation in drill holes S 1, S 13, and S 15, which are in the Clintwood quadrangle, have been slightly changed on the basis of a careful study of outcrops and many drill records east of the Pound quadrangle where the available data concerning the lower two Pennsylvanian formations are exceptionally good. As previously explained, the Lee-like sandstone near the foot of Pine Mountain and at the top of the canyon at The Breaks, naturally considered by both Butts and Stone to be the top of the Lee, is now known to be the stratum lying a few feet below the Kennedy coal bed, near the middle of the Norton formation. This sandstone is the cliff-former upon which Elkhorn City, Ky., is built, and the change in its correlation necessitates an entirely new conception of the stratigraphic position of strata in the Elkhorn district of eastern Kentucky (Pl. V).

In recent reports on Mingo and McDowell counties, West Virginia,¹ great cliffs on Tug Fork at and near War Eagle are correlated with the Nuttall sandstone and placed at the top of what is called the New River group, underlying the Kanawha group. The top of the Nuttall is a few feet below the Lower Banner coal horizon, and is the same as Campbell's Dotson sandstone. The bed mapped by Campbell as Dotson farther south, in the western and central parts of the Tazewell quadrangle, appears to be slightly higher in the section, probably just above the Upper Banner horizon. The sandstone mapped by Campbell as the Raleigh in the western part of the Tazewell quadrangle is the bottom-rock of the Jawbone coal, and is probably higher than the bed mapped as Raleigh in the eastern part of that quadrangle.

The coal beds called the Eagle and Campbell Creek (No. 2 Gas) by the West Virginia Geological Survey have been traced into the Clintwood and Bucu quadrangles and the names retained. The Eagle coal is locally known as the Middle War Eagle and Mohawk on Tug Fork. The Campbell Creek coal is the bed to which the name Lower Bolling was applied in the Pound quadrangle. This coal is locally called the Lower Elkhorn, Lower Marrowbone, Warfield, Freeburn, Burnwell, and Upper War Eagle in Pike County, Kentucky, and Mingo County, West Virginia. The Lower War Eagle coal of Tug Fork is the same as the Hagy of Virginia.

Local sections.

The following sections are inserted without comment, as it is believed that they are self-explanatory. They have been chosen from among a large number chiefly because they show an exceptional number of exposed beds and were made where dips are low. These local sections should be used with caution, as parts of every one of them are poorly exposed, and the intervals are not in every case the averages for the locality. Corrections that should be made in thicknesses of beds because of dip are indicated for each section; in the column showing intervals the necessary correction for dip has already been made.

¹ Hennen, R. V., and Reger, D. B., Logan and Mingo counties, West Va. Geol. Survey, 1914.

Hennen, R. V., Wyoming and McDowell counties, *idem*, 1915.

LOCAL SECTION 1.

On trails from mouth of Jerry Branch of Pound River to spur on west.

	Thickness. Feet.	Intervals. Feet.
Wise formation:		
Coal (Clintwood), elevation 1,795.....	..	
Sandstone, buff, coarse, shaly at base.....	70	
Coal (Eagle), elevation 1,725.....	..	70
Sandstone, as last above.....	40	
Concealed, probably shale and shaly sandstone, horizon of Blair coal bed near base.....	55	
Sandstone, white, compact, siliceous.....	20	
Shale, poorly exposed, horizon of Lyons coal bed near top	45	160
Coal (Glamorgan), elevation 1,565.....	..	
Gladeville sandstone:		
Sandstone, brownish-buff, coarse, weathers granu- lar	70	70
Norton formation:		
Shale, poorly exposed.....	50	
Sandstone, to river at mouth of Jerry branch....	25	75
	375	375

LOCAL SECTION 2.

From drill hole S 32, near the mouth of Cranesnest River, along road to top of ridge south of Davis School. Section 60 feet too long because of dip.

	Thickness. Feet.	Intervals. Feet.
Wise formation:		
Sandstone, buff, weathers red and granular, coarse. massive	35	
(Lyons coal horizon, elevation 1,847).....	..	32
Shale, chiefly, may include thin sandstones.....	65	
(Glamorgan coal horizon, elevation 1,782).....	..	58
Gladeville sandstone:		
Sandstone, buff, compact, massive, middle part not well exposed.....	55	50
Norton formation:		
Shale	55	
Sandstone, compact, massive, cross-bedded.....	30	
Shale, upper half doubtful.....	40	
Shale streak, black, carbonaceous (Hagy coal horizon), elevation 1,602.....	..	112
Interval, probably shale.....	20	
Sandstone, compact, massive.....	20	
Shale	40	
Coal bloom (Splash Dam, upper bench), ele- vation 1,522.....	..	72
Shale	10	
Coal bloom (Splash Dam, lower bench), ele- vation 1,512.....	..	9

	Thickness. Feet.	Intervals. Feet.
Norton formation:		
Shale	8	
Sandstone, compact, massive	22	
Interval, chiefly shale	40	
Sandstone	5	
Concealed	12	
(Estimated position of Upper Banner coal horizon, elevation 1,425)	..	78
Concealed	83	
Shale	22	
Sandstone	5	
Concealed	25	121
	592	532

Section continued in log of drill hole S 32.

LOCAL SECTION 3.

From drill hole S 1 on Cranesnest River up road to Hibbitts Gap, thence west to top of ridge near triangulation station. Section 130 feet too short because of dip.

	Thickness. Feet.	Intervals. Feet.
Wise formation:		
Sandstone, not well exposed	30	
Shale	10	
Coal (Clintwood) and partings, elevation 2,045 ..	8	60
Concealed	15	
Sandstone, white, compact, siliceous	18	
Shale, probably, not well exposed	20	
Coal (Blair), elevation 1,992	..	65
Sandstone, medium- to fine-grained	20	
Shale, apparently, not well exposed	15	
Coal, thin	..	44
Shale	10	
Coal (Lyons), elevation 1,947	..	12
Shale (Glamorgan coal horizon near base)	50	60
Gladeville sandstone:		
Sandstone, coarse, friable, fine-grained and thin- bedded at top	85	100
Norton formation:		
Shale	75	
Coal bloom	..	95
Sandstone, coarse-grained, conglomeratic in mid- dle	25	
Coal bloom	..	30
Shale, sandy	15	
Sandstone, coarse-grained	5	
Concealed	5	
Coal	..	30
Shale, sandy	50	
Coal streak	..	60
Shale	15	

	Thickness. Feet.	Intervals. Feet.
Norton formation:		
Sandstone, coarse-grained at top, medium- to fine-grained below	50	
(Upper Banner coal horizon, elevation 1,572)...	..	80
Shale	50	
Sandstone, medium-grained.....	10	
Shale, not well exposed.....	20	95
	601	731

Section continued in log of drill hole S 1.

LOCAL SECTION 4.

From Trace Fork of Cranesnest River at south boundary of Clintwood quadrangle, west to top of ridge. Section 50 feet too short because of dip.

	Thickness. Feet.	Intervals. Feet.
Wise formation:		
Sandstone, white, siliceous, compact, very resistant	35	
Shale, poorly exposed in upper part (Glamorgan coal horizon near base).....	100	145
Gladeville sandstone:		
Sandstone, buff, weathers brownish-red and granular, coarse, massive, forms cliffs.....	100	100
Norton formation:		
Shale, very poorly exposed.....	95	
Sandstone, buff, very coarse-grained in part, forms cliffs	25	
Concealed	50	
Sandstone, medium-grained to coarse.....	30	
Concealed	60	
Sandstone, medium-grained	15	
Concealed	10	
Sandstone, coarse-grained, massive.....	15	
Concealed	20	
(Estimated position of Upper Banner coal, elevation 2,080)	..	360
Concealed	10	
Sandstone, medium-grained to coarse.....	15	25
	580	630

Stratigraphic interval to top of drill hole S 12 is 135 feet.

LOCAL SECTION 5.

West along road from McClure River near Road Branch to knob on Big Ridge near Burnt Field School.

	Thickness. Feet.	Intervals. Feet.
Wise formation:		
Sandstone, white, siliceous, very compact.....	15	
Shale with some shaly sandstone (Glamorgan coal horizon near base).....	70	85
Gladeville sandstone:		
Sandstone, reddish-brown, arkosic, coarse, massive	75	75
Norton formation:		
Shale	75	
Sandstone, buff, coarse.....	35	
Shale	40	
Coal (Hagy), elevation 1,745.....	1	151
Shale	5	
Sandstone, brownish-buff, coarse, compact.....	45	
Shale, with a little sandstone.....	35	
Coal bloom (Splash Dam), elevation 1,660.....	..	85
Sandstone, buff, compact, with a little shale and faint coal bloom in middle.....	65	
Shale	10	
Coal bloom (Upper Banner, upper bench), elevation 1,595	..	75
Shale, sandy	10	
Coal bloom (Upper Banner, lower bench), elevation 1,585)	..	10
Shale	70	
Coal bloom (Lower Banner), elevation 1,515....	..	70
Sandstone, buff, coarse, compact.....	25	
Shale and a little fine-grained sandstone.....	60	85
	636	636

LOCAL SECTION 6.

From McClure River near Big Branch to Bearpen Gap, thence south on Big Ridge.

	Thickness. Feet.	Intervals. Feet.
Wise formation:		
Sandstone, white, weathers red and granular.....	45	
Concealed	48	
Sandstone, white, siliceous, compact.....	22	
Shale, black at base.....	25	
Coal (Glamorgan), elevation 2,078.....	1	141
Gladeville sandstone:		
Sandstone, light buff, coarse, massive, weathers red and granular	100	100
Norton formation:		
Shale, dark blue and drab, lower part exposed in Bearpen Gap	70	

	Thickness. Feet.	Intervals. Feet.
Norton formation:		
Sandstone, buff, very coarse, forms cliffs.....	40	
Shale, blue	20	
Sandstone, as last above.....	40	
Shale and inconspicuous sandstone.....	70	
Shale, sandy, with 3 coal beds 15 feet apart, and each less than 13 inches thick (Splash Dam) ..	30	
Sandstone, buff, shaly at top, coarse and massive below	50	
Coal bloom (Upper Banner, upper bench), ele- vation 1,658	..	320
Shale, sandy, and shaly sandstone.....	100	
Coal bloom (Lower Banner), elevation 1,558...	..	100
Sandstone, buff, coarse to fine-grained.....	70	
Sandstone, buff, fine-grained, mostly thin-bedded..	70	140
	801	801

LOCAL SECTION 7.

*Along road from mouth of Roaring Fork northeast to top of ridge. Section
30 feet too long because of dip.*

	Thickness. Feet.	Intervals. Feet.
Wise formation:		
Sandstone, white, weathers reddish, granular, shaly, with ferruginous bands in middle.....	35	
Coal bloom (Glamorgan), elevation 2,597.....	..	35
Gladeville sandstone:		
Sandstone, weathers reddish, granular, shaly in part	70	
Sandstone, light brownish-gray, coarse-grained, massive	65	125
Norton formation:		
Shale, with some sandstone, not well exposed....	165	
Sandstone, brownish-gray, in part very coarse, massive	40	
Concealed	10	
Sandstone, thin-bedded, resistant.....	40	
Sandstone, thin-bedded, and shale.....	45	
Coal bloom (Splash Dam), elevation 2,162.....	..	280
Sandstone, very coarse-grained, massive.....	13	
Sandstone, fine-grained, thin-bedded.....	15	
Sandstone, coarse-grained, massive, thin-bedded in part	35	
Concealed	25	
Coal (Upper Banner), elevation 2,074.....	..	88
Concealed	15	
Sandstone, coarse-grained, massive.....	20	
Concealed	80	
Sandstone, drab, coarse-grained.....	5	
Coal (Lower Banner), elevation 1,951.....	3	123
Sandstone, coarse-grained, massive.....	40	
Sandstone, drab, mostly fine-grained and thin- bedded	135	
Concealed	45	

	Thickness. Feet.	Intervals. Feet.
Norton formation:		
Shale and sandy shale.....	20	
Coal bloom (Kennedy), elevation 1,711.....	..	240
Sandstone, coarse-grained, massive.....	35	
Concealed	35	
Sandstone, massive	15	85
	1,006	976

Section continued in log of drill hole S 23.

LOCAL SECTION 8.

Up spur to west and north at sharp bend in Buffalo Creek, one mile east of mouth.

	Thickness. Feet.	Intervals. Feet.
Gladeville sandstone:		
Sandstone, weathers brownish-red, coarse, massive, not well exposed at top.....	70	70
Norton formation:		
Shale	70	
Sandstone, medium-grained, not well exposed.....	25	
Shale	15	
Sandstone, very coarse, massive.....	20	
Shale	20	
Sandstone, coarse, massive, forms cliffs.....	50	
Shale, mostly sandy and with some fine-grained sandstone	180	
Sandstone, fine-grained	10	
(Upper Banner coal horizon, elevation 1,812) ..	..	390
Shale	45	
Sandstone, medium-grained	12	
Shale	30	
(Lower Banner coal horizon, elevation 1,725) ..	..	87
Sandstone, coarse, massive, forms cliffs.....	55	
Shale, sandy in part, and with some fine-grained sandstone	80	135
	682	682

LOCAL SECTION 9.

Up spur to northeast at the mouth of Buffalo Creek.

	Thickness. Feet.	Intervals. Feet.
Norton formation:		
Shale	100	
Sandstone, coarse, massive.....	30	
Concealed	5	
(Upper Banner coal horizon, elevation 1,875) ...	..	135
Shale, sandy, and fine-grained, thin-bedded sand- stone	59	
Sandstone, medium- to fine-grained, thin-bedded...	12	
Shale, and some fine-grained, thin-bedded sand- stone	55	
(Lower Banner coal horizon, elevation 1,749....	..	125

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	Thickness. Feet.	Intervals. Feet.
Norton formation:		
Sandstone, coarse, massive, cliff-making.....	50	
Concealed	30	
Shale, sandy in part.....	110	
Concealed	15	
(Kennedy coal horizon, elevation 1,544).....	..	205
Sandstone, coarse, massive, cross-bedded.....	50	50
	515	515

Section continued in log of drill hole S 22.

LOCAL SECTION 10.

Up trail to north from Lick Creek of Russell Fork, one-half mile northeast of Counts School.

	Thickness. Feet.	Intervals. Feet.
Gladeville sandstone:		
Sandstone, buff, weathers reddish-brown, coarse, massive	60	60
Norton formation:		
Shale, light drab.....	45	
Sandstone, coarse, massive.....	40	
Shale	55	
(Hagy coal horizon, elevation 1,885).....	..	140
Sandstone, massive	20	
Shale, drab, in part contorted.....	50	
Coal bloom (Splash Dam, upper bench), elevation 1,815	..	70
Shale, drab, in part contorted.....	35	
Sandstone, coarse, massive, weathers granular....	25	
Shale	10	
Sandstone, coarse, massive, weathers granular....	25	
(Upper Banner coal horizon, elevation 1,720) ..	..	95
Shale	80	
(Lower Banner coal horizon, elevation 1,640) ..	..	80
Sandstone, coarse-grained, massive.....	35	
Shale, dark drab	25	60
	505	505

LOCAL SECTION 11.

Up trail to east and southeast from drill hole C 82 on Fryingpan Creek, three-quarters of a mile south of Bucu. Section 40 feet too long because of dip.

	Thickness. Feet.	Intervals. Feet.
Norton formation:		
Sandstone, light buff, coarse-grained, weathers granular	120	
Shale	90	
Coal bloom (Splash Dam, upper bench), elevation 2,425	1	211

Norton formation:	Thickness. Feet.	Intervals. Feet.
Shale	20	
Coal (Splash Dam, lower bench), elevation 2,405	..	20
Sandstone, medium-grained in upper part, coarse below	85	
Coal bloom (Upper Banner), elevation 2,315... ..	5	90
Shale, and thin sandstones.....	105	
(Lower Banner coal horizon, elevation 2,210)	..	100
Sandstone, medium-grained to coarse, massive.....	100	
Shale	40	
Sandstone, mostly medium-grained, forms bench..	30	
Shale	50	
Sandstone, medium-grained to coarse at top, fine-grained and shaly below.....	35	
Shale	15	
(Kennedy coal horizon, elevation 1,940).....	..	255
Sandstone, coarse, massive, forms strong cliff.....	65	
Shale, not well exposed at base.....	35	
Sandstone, medium-grained to coarse, forms cliff...	61	
Concealed	165	
(Garden Hole coal horizon, elevation 1,614).....	..	316
Concealed	30	30
	1,062	1,022

Section continued in log of drill hole C 82.

LOCAL SECTION 12.

From Cane Gap southwest along road to top of Sandy Ridge.

Norton formation:	Thickness. Feet.	Intervals. Feet.
Sandstone, badly weathered.....	10	
Shale	30	
Sandstone, fine-grained	15	
Shale	70	
Coal bloom (Kennedy), elevation 2,505.....	..	125
Sandstone, fine-grained in upper half, coarse below	65	
Coal bloom (Aily ?), elevation 2,440.....	..	65
Sandstone, fine-grained, shaly in part.....	60	
Sandstone	95	
Shale	5	
Coal bloom, elevation 2,280.....	..	160
Shale, with thin sandstone in middle.....	30	
Concealed	20	
Sandstone, medium-grained	15	
Concealed, some sandstone in lower part.....	45	
(Garden Hole coal horizon, elevation 2,170)	..	110
Sandstone, fairly coarse, compact, massive.....	30	
Shale	15	
Sandstone, medium-grained	45	
Shale, blue	10	
Shale and fine-grained, shaly sandstone.....	40	

	Thickness. Feet.	Intervals. Feet.
Norton formation:		
Sandstone, medium-grained	15	
Shale	15	
Coal bloom, elevation 2,000.....	..	170
Sandstone, coarse-grained, not well exposed.....	24	
Coal (Tiller and Jawbone), elevation 1,965, re- ported thickness	11	35
	665	665

LOCAL SECTION 13.

*Up spur to northwest from Lambert Fork of Indian Creek, one-half mile
northeast of mouth.*

	Thickness. Feet.	Intervals. Feet.
Norton formation:		
Sandstone, medium-grained to coarse and massive, lower part not well exposed.....	60	
Concealed, probably shale	40	
Sandstone, not well exposed.....	15	
Shale	15	
Sandstone, coarse at top, medium-grained below, forms conspicuous cliff.....	25	
Coal	..	155
Shale	20	
Coal (Garden Hole), elevation 2,025.....	..	20
Concealed	10	
Sandstone, coarse and very massive, forms cliff....	55	
Concealed, shaly at top.....	70	
Coal (Jawbone), elevation 1,890.....	..	135
Sandstone, medium-grained	20	
Concealed, partly sandstone	70	
Coal (Tiller), elevation 1,800.....	..	90
Concealed	30	
Sandstone, medium-grained to very coarse, with a few pebbles, not well exposed at top.....	65	
Concealed, some sandstone in middle part.....	60	155
Lee formation:		
Sandstone, compact, resistant, very coarse.....	45	45
	600	600

LOCAL SECTION 14.

From Council north along road to top of ridge.

	Thickness. Feet.	Intervals. Feet.
Norton formation:		
(Splash Dam coal horizon, elevation 2,520)....	..	
Sandstone, reddish-brown, coarse, granular.....	25	
Shale, sandy shale, and some sandstone, poorly ex- posed	115	
Shale, good exposure.....	40	
(Lower Banner coal horizon, elevation 2,340) ..	..	180

Norton formation:	Thickness. Feet.	Intervals. Feet.
Sandstone, mostly coarse and granular, forms ledge	40	
Shale, in part sandy.....	40	
Sandstone, fairly coarse, forms ledge.....	8	
Shale	20	
Sandstone, fairly coarse.....	5	
Shale, with some sandstone near top, not well exposed	80	
Coal and partings (Kennedy, location 319), elevation 2,142	5	198
Clay and shale	10	
Sandstone, coarse, resistant, forms conspicuous ledge	20	
Shale, chiefly, not well exposed.....	72	
Coal bloom, elevation 2,040.....	..	102
Shale	5	
Sandstone, fairly coarse, shaly at top.....	25	
Coal bloom, elevation 2,010.....	..	30
Shale	8	
Sandstone, not conspicuous.....	25	
Shale	37	
Coal bloom (Garden Hole) thin, elevation 1,940.....	..	75
Sandstone, fairly coarse, resistant.....	29	
Shale, well exposed in upper part.....	140	
(Jawbone coal horizon, elevation 1,771).....	..	169
Sandstone, coarse, weathers granular, few small pebbles at base.....	50	
Shale	5	
Coal bloom (Tiller), elevation 1,716.....	..	55
Sandstone, coarse, very compact.....	30	
Concealed, probably sandstone.....	15	
Shale, bluish	25	70
	874	874

LOCAL SECTION 15.

From Hurricane Creek at mouth of Rockhouse Branch up spur to northeast.

Norton formation:	Thickness. Feet.	Intervals. Feet.
Sandstone, medium-grained, weathers soft.....	15	
Shale	15	
Sandstone, coarse, weathers soft and granular...	20	
Shale, with thin, fine-grained sandstones in upper part	110	
(Lower Banner coal horizon, elevation 2,110)...	..	160
Sandstone, coarse, massive.....	35	
Shale	70	
Sandstone, fairly coarse.....	10	
Shale	65	
(Kennedy coal horizon, elevation 1,930).....	..	180
Sandstone, mostly coarse, weathers soft at top, lower 50 feet forms cliff	86	
Shale, mostly drab.....	42	

28 COAL RESOURCES OF THE CLINTWOOD AND BUCU QUADRANGLES

	Thickness. Feet.	Intervals. Feet.
Norton formation:		
Shale, mostly sandy, with some fine-grained sandstone	92	
Sandstone, fairly coarse.....	5	
Shale, not well exposed.....	10	
(Garden Hole coal horizon, elevation 1,695)...	..	235
Sandstone, fairly coarse and massive at top, medium-grained, thin-bedded and cross-bedded below	75	75
	650	650

LOCAL SECTION 16.

From Fox Creek, one mile east of the mouth of Left Fork, up spur to northwest.

	Thickness. Feet.	Intervals. Feet.
Wise formation:		
Shale	30	30
Gladeville sandstone:		
Sandstone, coarse-grained, weathers reddish-brown and granular, forms conspicuous cliff.....	75	75
Norton formation:		
Shale, grayish-yellow to drab.....	80	
Sandstone, fine-grained at top to fairly coarse below	30	
Concealed, probably sandstone.....	10	
Shale	20	
(Hagy coal horizon, elevation 1,885).....	..	140
Sandstone, medium-grained to fairly coarse.....	30	
Concealed	15	
Sandstone, fine-grained, shaly.....	20	
Shale, mostly sandy.....	55	
(Splash Dam coal horizon, elevation 1,765)....	..	120
Sandstone, medium-grained to coarse, lower part compact and forms conspicuous cliff.....	70	
(Upper Banner coal horizon, elevation 1,695) ..	..	70
Sandstone, fine-grained, shaly.....	30	
Sandstone, medium-grained to fairly coarse.....	20	
Concealed, probably mostly shale.....	25	
(Lower Banner coal horizon, elevation 1,620) ..	..	75
Sandstone, medium-grained	20	
Concealed	25	
Sandstone, fine-grained, shaly.....	25	70
	580	580

LOCAL SECTION 17.

From Russell Fork at mouth of Fox Creek up spur to southeast.

	Thickness. Feet.	Intervals. Feet.
Norton formation:		
Shale	25	
(Splash Dam coal horizon, elevation 1,795)....	..	25
Sandstone, coarse, cliff-forming, not well exposed in upper part	80	
(Upper Banner coal horizon, elevation 1,715) ..	..	80
Shale, mostly bluish, good exposure.....	75	
(Lower Banner coal horizon, elevation 1,640)....	..	75
Sandstone, very coarse and massive.....	30	
Shale, very sandy, and shaly sandstone.....	125	
Sandstone, medium-grained	25	
Concealed	10	
(Kennedy coal horizon, elevation 1,450).....	..	190
Sandstone, medium-grained to fairly coarse.....	30	
Sandstone, fine-grained and in part shaly.....	70	
Sandstone, medium-grained	15	115
	485	485

LOCAL SECTION 18.

*Northeast from Russell Prater Creek at location 355 to high knob northwest
of Russell Prater—Poplar Creek gap.*

	Thickness. Feet.	Intervals. Feet.
Wise formation:		
Sandstone, white, compact, weathers orange-red, coarse-grained	10	
Shale, sandy, at top and with thin medium-grained sandstone	170	
(Clintwood coal horizon, elevation 2,138).....	..	180
Sandstone, coarse, arkosic, weathers granular, mas- sive	90	
Concealed	15	
Coal (Eagle), elevation 2,033.....	..	105
Interval, chiefly shale	130	
(Glamorgan coal horizon, elevation 1,903).....	..	130
Gladeville sandstone:		
Sandstone, buff, medium-grained to coarse, forms cliff, not well exposed at base.....	60	60
Norton formation:		
Concealed	30	
Shale, sandy in part.....	120	
Coal (Hagy, location 355), elevation 1,690....	3	153
	628	628

LOCAL SECTION 19.

From Russell Prater Creek, about one mile southwest of Prater, north to top of ridge.

	Thickness. Feet.	Intervals. Feet.
Wise formation:		
Shale	50	
(Clintwood coal horizon, elevation 2,060)	..	50
Sandstone, buff, mostly coarse, massive, forms cliffs	95	
(Eagle coal horizon, elevation 1,965)	..	95
Shale and a few thin sandstones, not well exposed..	165	
(Glamorgan coal horizon, elevation 1,800)	..	165
Gladeville sandstone:		
Sandstone, medium-grained to coarse	60	
Norton formation:		
Shale	60	
Sandstone, medium-grained, resistant in part....	50	
Shale	30	
(Hagy coal horizon, elevation 1,600)	..	200
Sandstone, medium-grained, coarse at base	50	
Concealed	50	
Shale	10	
Sandstone, medium-grained	10	
Shale	10	
Sandstone, medium-grained	10	140
	650	650

LOCAL SECTION 20.

From Russell Prater Creek one-fourth mile northeast of Mart, up spur to north and west to triangulation station.

	Thickness. Feet.	Intervals. Feet.
Wise formation:		
Concealed to triangulation station (elevation 1,973)	13	
Shale	30	
Concealed	50	
Sandstone, very coarse-grained and light-gray at top, massive	60	
Shale, sandy	15	
Coal (Eagle), elevation 1,805	..	168
Shale, sandy in part	70	
Coal (Blair), elevation 1,735	..	70
Sandstone, coarse-grained, massive	50	
Concealed, probably shale in lower part	50	
(Glamorgan coal horizon, elevation 1,635)	..	100
Gladeville sandstone:		
Sandstone, medium-grained to coarse, massive....	50	50
Norton formation:		
Shale	72	
Sandstone, medium-grained, forms cliff	35	

	Thickness. Feet.	Intervals. Feet.
Norton formation:		
Concealed	95	
Sandstone, fine-grained	10	
Shale, sandy	15	
Coal (Splash Dam, location 346), elevation 1,355	3	230
Sandstone, fairly coarse, massive.....	55	
Shale, drab	15	70
	688	688

LOCAL SECTION 21.

From location 389, on Levisa Fork three-fourths mile northwest of Hanger, along road to southeast for one-half mile, thence up spur to north.

	Thickness. Feet.	Intervals. Feet.
Norton formation:		
Sandstone, coarse, resistant, forms cliff.....	30	
Shale	100	
(Lower Banner coal horizon, elevation 1,870)...	..	130
Sandstone, mostly fine-grained and thin-bedded and sandy shale	50	
Sandstone, fairly coarse at top, medium-grained below	70	
Concealed	60	
(Kennedy coal horizon, elevation 1,690).....	..	180
Sandstone, coarse, forming strong cliffs.....	90	
Shale, in part blue, interbedded with thin sandstones	115	
(Garden Hole coal horizon, elevation 1,485)...	..	205
Sandstone, fairly coarse, micaceous, forms cliff....	60	
Shale, mostly blue-black	50	
Shale, blue at base, with thin beds of sandstone..	44	
Coal (Tiller), elevation 1,329.....	2	156
Shale	10	
Sandstone, coarse, forms cliff in lower part.....	60	70
	741	741

LOCAL SECTION 22.

From Levisa Fork near mouth of Bens Branch (location 391) up spur to north.

	Thickness. Feet.	Intervals. Feet.
Norton formation:		
Kennedy coal horizon, elevation 1,500.....	..	
Sandstone, upper half coarse and compact, lower half finer-grained, forms conspicuous cliffs...	115	
Concealed, probably mostly sandy shale, with some sandstone in lower part (Garden Hole coal horizon near base)	105	
Sandstone, very fine-grained, forms ledge.....	10	
Concealed, mostly shaly.....	80	
(Jawbone coal horizon, elevation 1,190).....	..	310

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Norton formation:	Thickness. Feet.	Intervals. Feet.
Sandstone, very coarse, quartz pebbles at base....	30	
Shale	11	
Sandstone	20	
Shale, blue	18	
Coal (Tiller, location 391), elevation 1,110....	1	80
Clay, blue, with abundant stems.....	4	
Shale, drab, sandy, ripple-marked.....	4	8
	398	398

LOCAL SECTION 23.

Up spur to northeast from forks of road opposite mouth of Little Prater Creek.

Norton formation:	Thickness. Feet.	Intervals. Feet.
Sandstone, fairly coarse, forms conspicuous cliff..	80	
Shale, sandy	25	
Sandstone, medium-grained, forms ledge.....	20	
Shale, sandy	20	
(Splash Dam coal horizon, elevation 1,630)...	..	145
Sandstone, coarse, massive, forms conspicuous cliff	65	
(Upper Banner coal horizon).....	..	65
Shale, mostly sandy.....	55	
Sandstone, medium-grained	10	
Shale, sandy	35	
(Lower Banner coal horizon, elevation 1,465)	..	100
Sandstone, fairly coarse at top, fine-grained below, forms cliffs	75	
Shale, sandy, and some fine-grained, shaly sandstone	75	
(Kennedy coal horizon, elevation 1,315).....	..	150
Sandstone, coarse, massive, forms very conspicuous cliff	100	
Shale, sandy, with fine-grained, shaly sandstone at base	72½	
Coal (Garden Hole), elevation 1,140.....	2½	175
Shale, in part sandy.....	8	
Sandstone, forms cliff.....	20	
Shale, in part blue.....	30	58
	693	693

LOCAL SECTION 24.

From mouth of Big Lick Branch of Trace Fork of Prater Creek northwest along road to gap, thence up spur to north. Section 50 feet too short because of dip.

	Thickness. Feet.	Intervals. Feet.
Wise formation:		
Shale	20	
(Clintwood coal horizon, elevation 2,252).....	..	20
Sandstone, coarse, massive, white in lower part....	60	
Concealed	20	
(Approximate position of Eagle coal, elevation 2,172)	..	80
Concealed	30	
Shale	40	
Sandstone, not well exposed.....	10	
Interval, chiefly shale.....	70	
(Glamorgan coal horizon, elevation 2,022)....	..	150
Gladeville sandstone:		
Sandstone, mostly coarse, not well exposed.....	65	65
Norton formation:		
Concealed	25	
Shale, mostly sandy, and thin sandstones.....	115	
Sandstone, fine-grained	25	
Shale	40	
Sandstone, coarse in part, micaceous.....	20	
Coal (Splash Dam, location 439), elevation 1,730	2	272
Concealed, some sandstone in upper part.....	30	
Sandstone, not well exposed at top.....	20	
Concealed	85	
Shale, mostly sandy, with some thin, fine-grained sandstones	135	
Sandstone, fine-grained, thin-bedded.....	10	
(Kennedy coal horizon, elevation 1,450)	..	280
Sandstone, not well exposed.....	65	
Concealed	50	
Sandstone, fine-grained to coarse.....	40	
Shale, sandy, and fine-grained, thin-bedded sandstone	38	
Coal (Garden Hole, location 417), elevation 1,255	2	202
	1,017	1,067

LOCAL SECTION 25.

Southward on road along upper part of Trace Fork of Prater Creek, from a mile southwest of Leemaster to gap, thence up spur to west.

	Thickness. Feet.	Intervals. Feet.
Wise formation:		
Sandstone, coarse, massive, weathers soft and granular	40	
Shale, sandy in part, with thin sandstone bed near middle	65	
(Glamorgan coal horizon, elevation 2,135)....	..	105

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	Thickness. Feet.	Intervals. Feet.
Gladeville sandstone:		
Sandstone, uniformly coarse and very massive, top weathers round and smooth.....	60	60
Norton formation:		
Shale, top not well exposed, sandy at base.....	100	
Concealed	20	
Sandstone, coarse, forms ledge.....	20	
Shale, sandy at top, drab to blue at base.....	30	
Coal (Hagy, location 444), elevation 1,911....	3	173
Concealed, probably shale	10	
Sandstone, medium-grained, massive	15	
Shale, sandy	35	60
	308	308

LOCAL SECTION 26.

From coal opening 100 yards southwest of location 419, on Crooked Branch of Prater Creek, one-fourth mile southeast along road, thence up spur to northwest.

	Thickness. Feet.	Intervals. Feet.
Norton formation:		
(Splash Dam coal horizon, elevation 2,225)....	..	
Sandstone, coarse to medium-grained, very massive in upper part, forms conspicuous cliffs.....	60	
(Upper Banner coal horizon, elevation 2,165) ..	..	60
Shale, in part sandy.....	155	
Sandstone, fine-grained	10	
Shale	53	
Sandstone, medium-grained, resistant.....	15	
Shale, mostly sandy.....	76	
Coal bloom (Kennedy), elevation 1,856.....	..	300
Sandstone, medium-grained to coarse, mostly compact, but weathers granular in parts, lower part most conspicuous.....	55	
Shale	52	
Sandstone, medium-grained, compact.....	15	
Shale, sandy	15	
Coal (location 419), elevation 1,717.....	2	139
Shale, sandy	60	
Coal (Garden Hole), elevation 1,655.....	2	62
	570	570

LOCAL SECTION 27.

From location 458 on Young's Branch of Garden Creek northwestward along path to gap, thence south along ridge.

	Thickness. Feet.	Intervals. Feet.
Wise formation:		
Shale	80	
Coal bloom (Glamorgan), elevation 2,490.....	..	80

	Thickness. Feet.	Intervals. Feet.
Gladeville sandstone:		
Sandstone, coarse, weathers reddish-brown and granular, massive, not well exposed in lower part	90	90
Norton formation:		
Shale	51	
Concealed, probably mostly shale.....	70	
Sandstone, fairly coarse, weathers granular, upper part not well exposed.....	90	
Shale	40	
Sandstone, coarse, resistant, forms ledge.....	25	
Shale, not exposed at base.....	55	
(Splash Dam coal horizon 2,078).....	..	232
Sandstone, coarse, forms ledge.....	20	
Concealed, probably mostly sandy shale and fine-grained sandstone, includes Lower Banner coal horizon in lower part.....	178	
Shale, sandy, chiefly, with thin fine-grained shaly sandstones	136	
Coal (Kennedy, location 458), elevation 1,740..	5	339
Sandstone, coarse, massive, compact.....	65	65
	907	907

LOCAL SECTION 28.

Southward on road along upper part of Whitt Fork of Garden Creek to gap, thence westward along path up spur to top of ridge. Section 40 feet long because of dip in lower part.

	Thickness. Feet.	Intervals. Feet.
Wise formation:		
Sandstone, coarse	10	
Concealed, probably mostly shale.....	40	
(Hagy coal horizon, elevation 2,727).....	..	50
Sandstone, coarse, massive.....	65	
Shale, sandy	20	
(Splash Dam coal horizon, elevation 2,642)....	..	85
Sandstone, coarse to medium-grained.....	45	
Shale	15	
Sandstone, fine-grained	10	
Shale, sandy	30	
(Lower Banner coal horizon, elevation 2,542) ..	..	100
Sandstone, coarse to medium-grained.....	35	
Shale, sandy	25	
Sandstone, fine-grained, and shale, not well exposed in lower part.....	175	
Coal (Kennedy, location 467), elevation 2,305..	2	237
Sandstone, coarse, compact, resistant.....	60	
Concealed	40	
Shale	40	
Coal, in opening under road, elevation 2,165..	..	120
Concealed	25	
Sandstone	20	
Shale, sandy and fine-grained, shaly sandstone, poor exposure	40	

	Thickness. Feet.	Intervals. Feet.
Wise formation:		
Sandstone, forms ledge.....	15	
Concealed	35	
Coal (Garden Hole) in opening under road, elevation 2,030	..	115
	747	707

LOCAL SECTION 29.

Northward along road from mouth of Negro Camp Branch of Road Fork to Carrie, thence one-fourth mile east on Sandy Ridge.

	Thickness. Feet.	Intervals. Feet.
Gladeville sandstone:		
Sandstone, orange-colored to reddish-brown, grades from fine-grained at base to very coarse and with a few small pebbles at top, upper part very resistant to weathering.....	115	115
Norton formation:		
Shale, with two thin sandstones.....	100	
Sandstone, coarse and compact, weathers light gray to brown	75	
Concealed	67	
Shale, in part sandy and with some fine-grained, thin-bedded sandstone	45	
Sandstone, coarse at base to fine-grained at top, resistant, forms cliff.....	45	
Concealed	10	
Coal bloom (Splash Dam), elevation 2,433.....	..	342
Sandstone, medium-grained, forms strong ledge...	30	
Concealed, probably shale.....	8	
Coal bloom (Upper Banner), elevation 2,395...	..	38
Shale, sandy	30	
Sandstone, fine-grained	5	
Concealed	80	
(Lower Banner coal horizon, elevation 2,280) ..	..	115
Sandstone, fine-grained at top, lower part coarse, forms strong cliff.....	60	
Shale, sandy	12	
Sandstone, fine-grained, forms ledge.....	20	92
	702	702

GEOLOGIC STRUCTURE.

Method of representation.

The position in which coal and other beds lie in a region in which there are few sharp folds is most readily shown by means of structure contours,—lines drawn so that each one of them connects points at which some easily recognizable reference stratum is at the same elevation. In part of the

quadrangles the Upper Banner coal bed has been chosen as the reference stratum, and in another part the Splash Dam coal bed, which is about 70 feet above the Upper Banner. By this method the direction of the dip and its magnitude in feet per mile or other unit can be quickly ascertained from the map.

Another use of the structure contours is to show the position of the outcrop of any bed on the topographic map or its depth beneath the surface where it is covered by other rocks. For example, if it is desired to find the position of the Kennedy coal bed at some point along Indian Creek, the elevation of the Upper Banner horizon shown by the structure contours is first noted. Then the interval between the Kennedy and the Upper Banner is ascertained by consulting the detailed descriptions of the Kennedy in the Indian Creek drainage basin, the generalized sections in Plate IV, or a local section for a neighboring exposure. As the Kennedy is below the Upper Banner, this interval subtracted from the elevation of the latter bed will give the elevation of the Kennedy. By turning to the topographic map the Kennedy outcrop can then be located by noting the position of the surface contour with the same elevation. If the bed under discussion is below the surface, the depth to which it is necessary to drill in order to reach it can be determined by subtracting the elevation of the bed from that shown by the topographic map at that point.

The usefulness of structure contours naturally depends largely on their accuracy. There are so many possible sources of error in this region that it is not maintained that absolute accuracy has been achieved. It is believed, however, that inaccuracies of more than 50 feet in vertical distance are very rare. Errors are most likely to be made where dips are exceptionally steep, as along Pine Mountain, near faulted and buckled areas like those on Russell Fork and in the southeastern part of the Bucu quadrangle, and where few coal beds were found, as along Pawpaw and Fox creeks and in some other areas.

Folds.

In the greater part of the quadrangles there is a general dip to the northwest averaging a little more than 50 feet to the mile. This general dip is not uniform, however, and is modified and to a large extent governed by a few large open folds, and is also locally modified by short low folds or wrinkles that are irregularly distributed and whose axes trend in different directions.

Middlesboro syncline.—All of the Virginia portion of the Clintwood quadrangle and part of the Bucu quadrangle lies in a broad fold that is synclinal, or concave upward. This fold, named by Campbell the Middlesboro syncline, extends from a few miles northeast of the Clintwood quadrangle southwest into Tennessee, being commonly 12 to 20 miles broad, and lying between Pine Mountain on the northwest and a broad arch or anticline on the southeast. It fades out northeast of Russell Fork, as will be explained in the description of the Pine Mountain fault.

The axis, or imaginary line toward which the strata on each side dip and which connects the lowest parts of the syncline, corresponds closely in position with the valley of Pound River and is continued in the same direction northeast of Russell Fork. Strata southeast of the axis dip, in general, to the northwest at very low angles, descending, for example, a vertical distance of 950 feet between the southeast corner of the Clintwood quadrangle and the mouth of Cranesnest River, a horizontal distance of $16\frac{1}{2}$ miles. Northwest of the axis the dip is to the southeast and gradually increases to about 33 degrees near the top of Pine Mountain. The southeast dips are caused by the Pine Mountain fault and continue to the points where it comes to the surface on the northwest slopes of the mountain. (See fig. 2.)

Sourwood Mountain anticline.—In the south-central part of the Bucu quadrangle there is a structure that is the reverse of a syncline, strata being convex upward and dipping away from the axis. This feature is the Sourwood Mountain anticline. Its axis is a curved line having a general north-south trend and terminating at both ends at faulted areas. Dips are, in general, to the west and northwest on its west side and east on its east side and average about 250 feet to the mile. The anticline plunges slightly to the north and is slightly modified by a very shallow cross-syncline at its south end.

Dry Fork anticline.—Another anticline affects a small area in the southeastern part of the Bucu quadrangle. This arch has a broad, flat top and a northeast-southwest trend and plunges slightly to the west. Except that strata south of the axis have general southerly dips, the anticline has not greatly affected the structure of the area. It is a stronger feature farther east, however, entering West Virginia at the head of Dry Fork and reaching as far northeast as Bramwell, W. Va. It appears to end on the southwest at the buckled and faulted area along Russell Fork, but may have extended farther southwest before differential movement took place in that area.

Faults.

In addition to the folds, faults have profoundly modified the structure and have exerted a marked influence on the economic possibilities of the region. A large part of the potentially coal-producing territory of southwest Virginia is bounded on both the northwest and the southeast by great thrust faults, the value of parts of several coal beds has been decreased by movements connected with this faulting, and buckling and faulting have made unavailable the deposits in narrow zones within the coal field.

Pine Mountain fault.—The rocks of the Virginia area were thrust up over those in Kentucky along the great Pine Mountain fault, which comes to the surface along the north face of Pine Mountain from Russell Fork into Tennessee. The fault dies out rapidly northeast of Russell Fork, and on Levisa Fork there is no trace of it or of the anticline from which it developed. According to recent work by Butts in the Clintwood and Pound quadrangles, the fault is compound in places, breaks having occurred along two planes that are close together everywhere and join in places (fig. 2). The first effect of the tremendous pressure from the southeast was probably the formation of a sharply overturned fold, near the axis of which the first fault originated. The rocks belonging to the Lee formation, on the hills northwest of the Pine Mountain escarpment in the Clintwood quadrangle were probably carried to that position by the first fault and are only small remnants that have escaped erosion. These rocks, which overlie undisturbed strata of the Wise formation, are nearly vertical in places, and at one place $1\frac{1}{2}$ miles west of Blowing Rock Gap are separated from Devonian black shale, brought up by the second fault, by overturned remnants of Pennington shale and Newman limestone. The second fault was at a lower angle and carried the rocks still higher, so that now the lower part of the Devonian black shale is in contact with beds in the Wise formation.

The vertical component of the thrust along the outcrop of the fault in the Clintwood quadrangle is 5,000 to 5,300 feet. In The Breaks, where the fault crosses Russell Fork north of the Clintwood quadrangle, the vertical displacement is only 600 to 800 feet and there is no evidence of overfolding or of more than one fault. It is probable that one of the faults ends near Skegg Gap, 2 miles west of The Breaks, where there has been differential movement or shearing along a nearly vertical plane in line with the zone of faulting and buckling on Russell Fork, in the Clintwood quadrangle.

Russell Fork faulted and buckled areas.—The rocks in several narrow areas along Russell Fork, one of which extends to Fryingpan Creek, are

shown on the geologic maps in the undifferentiated Pennsylvanian symbol because the rocks in them dip so steeply and irregularly in places that the exact position of formation boundaries is uncertain. The structure of these areas is complicated and will be explained only in outline.

One faulted area less than a mile wide lies along Russell Fork from near Sand Lick to the north boundary of the Clintwood quadrangle and continues on the north to Skegg Gap on Pine Mountain. Dips in this area, especially along its eastern border north of McClure River, are chiefly south of northeast at all angles between 5 and nearly 90 degrees. In places, however, there are steep dips to other points of the compass, and some shale beds are irregularly buckled and crumpled. In other places there has been little disturbance. This structural feature is primarily the result of shearing along one or more lines parallel with its long axis. The movements were evidently connected with the Pine Mountain faulting, and resulted in rocks on the southwest side of the faulted area moving farther to the northwest and becoming relatively higher than those on the northeast side. The northeasterly dips and much of the apparently irregular buckling were caused by a crowding together of the rocks on each side of the shearing planes. Finally, a reaction brought about normal faulting with the downthrow on the southwest, though not sufficient to lower the strata to the level of those on the northeast. The line of weakness developed by the fracturing of the rocks has determined the position of Russell Fork. The remarkably straight course of Fryingpan Creek in a continuation of the same northwest-southeast direction suggests a continuation of the shearing to the southeast, but no positive evidence of such an extension could be obtained along the lower part of the stream.

Dips in different directions, some at high angles, were noted at several places near the mouths of Pawpaw and Little Pawpaw creeks and along Russell Fork for a short distance southeast. The disturbance is most noticeable along the county road where it makes a cut-off near a sharp bend of the river half a mile south of Pawpaw Creek. The dips appear to have been caused by buckling resulting from incipient shearing.

A disturbed area whose long axis is in line with that of the one just mentioned was noted a short distance up Russell Fork. Along the river between Murphy and a point about a mile northeast, and for short distances back from the stream, there are dips of 50 degrees and less in several directions. There are distinct evidences of faulting at two points but the relationships are not very clear. It is probable that there has been shearing, accompanied by faulting, along a line from Indian northwest to Murphy

and beyond. As along the lower part of Russell Fork, strata on the southwest side of the fault moved to the northwest past those on the northeast side, but not far.

A very long, narrow area in which the strata are buckled and faulted extends from the north end of Big A Mountain northwest down Russell Fork for 8 miles, and thence to a point north of Abners Gap and beyond. This structural feature was caused by shearing along a fault whose position can not be exactly located everywhere, but which lies approximately as shown on the geologic map of the Bucu quadrangle. Beds north of the fault remained nearly stationary during the movement, but those on the south side were forced a short distance northwest and were folded to form or accentuate the feature described as the Sourwood Mountain anticline. Beds for a short distance on both sides of the fault are buckled in places, but less than in other areas mentioned. Buckling was greatest at the northwest end of the area, on Priest Fork, where there was probably no clean-cut faulting. The shearing was evidently the result of the great pressures which deformed the rocks in the southeast corner of the quadrangle.

Faults in the southeast corner of the Bucu quadrangle.—Rocks in the southeast corner of the Bucu quadrangle were strongly folded, overturned, and overthrust to the northwest along at least ten great faults. Except in a narrow area west of Weaver Creek, however, the strata are all pre-Pennsylvanian and contain no commercial coal deposits, so that details of the structure will not be given here. Since the coal-bearing beds that formerly overlay the older rocks have been raised and completely removed by erosion, the coal field is bounded on the southeast by these overthrust beds. Pennsylvanian strata underlie the border of the faulted area in places, but the coal in them can never be profitably mined. Southwest of Big A Mountain there are rocks shown on the geologic map in the undifferentiated Pennsylvanian symbol. These beds all dip southeast at angles of 30 to 70 degrees and include the Lee and lower part of the Norton formation, overturned and forced over younger Pennsylvanian beds along a thrust fault. Coal-bearing rocks west and north of the faulted area are not much disturbed, and even those close to the overthrusts dip less than 1 degree except in a few small areas.

Other movements.—During the movements described above there was a general tendency for higher beds to be forced slightly farther northwest than those below them. This differential movement has been effected chiefly by buckling within shale beds, so that many exposures of shale show steep and irregular dips in localities in which all the more massive sand-



Views of coal beds showing movement along bedding planes: (A) Kennedy coal in railroad cut near mouth of Roaring Fork; (B) Tiller and Jawbone coal one mile southwest of Duty (location 244).

stones and most other beds have only the very gentle dips that characterize the greater part of the coal field. Movement has taken place in several coal beds also, so that the coal is crushed and fractured and in places mixed with slickensided shale fragments to form "rash." Movement along the Kennedy coal bed and the rocks immediately over it has been especially common in the area south and west of Russell Fork, the coarse, massive sandstone beneath the coal forming a comparatively immovable stratum over which rode the thin-bedded rocks above. Parts of the Jawbone and partings in other coal beds are similarly affected, especially near faulted areas.

Normal faults are uncommon but are not unknown. All those observed were small, the beds on the downthrow side having been dropped only a few inches to 30 feet below their normal position.

ECONOMIC GEOLOGY

GENERAL DESCRIPTION OF COAL BEDS.

Introduction.

The Clintwood and Bucu quadrangles contain many beds of high-grade coking coal, the quality of which will be described more completely in another part of this report. At least thirteen of these beds are minable in one or more localities under present commercial conditions, though no bed is sufficiently thick in all localities to compete with thicker deposits that will be available in this and neighboring areas for years to come. As shown by the tables of ultimately available tonnages, there is a great quantity of coal that will form an important reserve for the near and distant future.

The thicknesses and general characters of each coal bed have a wide range, even in neighboring localities. Only the most complete and thorough prospecting can determine the exact possibilities in advance of mining, and such detailed prospecting has been undertaken in only about a fourth of the area. In addition to the differences in the tonnage per acre of a bed or zone from place to place, another factor of uncertainty arises from the fact that many beds split into two or more parts where shale partings thicken considerably. Very few exposures show more than 3 feet of coal without partings half an inch or more thick, the most common being shale or hard clay. The term "rash" is locally applied to an intimate mixture of coal and shale, in many places contorted and slickensided by movements along the bedding planes. Thin layers of bone and also of cannel form parts of some coal beds.

The thicknesses of coal, the intervals between beds, and other economic factors are described by drainage basins in a succeeding section of this report. In this place only brief summaries of the characteristics of each bed will be given. The intervals used are averages only, and will not apply exactly to all parts of the quadrangles. Maximum and minimum intervals are given in the detailed descriptions by drainage basins and in the generalized sections (Pl. IV). Many local intervals are shown in the local sections.

Coal beds in the Lee formation.

The Lee formation is fully exposed in this area only on the southeast slope of Pine Mountain, and where the formation has been overturned and

thrust over younger beds southwest of Big A Mountain. No economically important coal beds were found in these places, though exposures are poor and some fairly thick deposits might have escaped notice. The fact that only very thin Lee coals are present a short distance north of the Clintwood quadrangle in The Breaks, where most of the Lee is clearly exposed, indicates that there is very little minable coal in the formation in at least the northern part of the quadrangles. A number of Lee coal beds are shown in the drill records of the Clinchfield Coal Corporation (Pls. II and III), but their thicknesses have not been made public. A 30-inch bed was found near the top of the formation in exposures on Indian Creek.

In Wise, Lee, and Scott counties, Virginia, where the Lee is exposed in a large area, it contains a number of coal beds that are thin in most places and a few that are fairly thick in small districts. About the same condition probably prevails in the south half of these quadrangles. Rocks equivalent to the Lee in the famous Pocahontas field, about 30 miles east of the quadrangles, include very thick and pure coal beds. These coals thin to the west, however, and the places of some of the most important beds are taken by thick basal conglomerates in at least part of the Clintwood quadrangle.

Tiller coal bed.

Although there are coal deposits in places in the 200-foot interval between it and the top of the Lee formation, the lowest coal bed of much commercial importance is the Tiller. The rocks in the interval are alternating shales and sandstones with no striking characteristics, though an exceptionally coarse and locally conglomeratic sandstone lies a few feet below the coal. The Tiller horizon is exposed only along Indian Creek and its tributaries, along Fryingpan Creek near Bucu, along the upper part of Russell Fork, in a small area on Musick Fork of Weaver Creek, along part of Levisa Fork, and in the southern foothills of Pine Mountain. The name Tiller was applied by Stone in his report on the coal resources of the Russell Fork basin to the thick coal bed on Indian and Cane creeks. As the upper part of this thick deposit is now known to be the equivalent of the Jawbone, the name Tiller is restricted in this report to the lower part.

Although the Tiller is concealed beneath the surface in much of the area, it may be safely estimated that it is a minable bed containing about 4 to 6 feet of coal in the south third of the Bucu quadrangle. It will probably be mined on a large scale in the near future, and a beginning has already been made at the "slope mine" of the Clinchfield Coal Corporation on Hurricane Fork, a short distance south of the Bucu quadrangle. In a

strip extending southeast from Bucu the Tiller is united with the overlying Jawbone coal to form a very thick bed. Exposures in the southern and central parts of the Indian Creek drainage basin show 7 to 15 feet of minable coal in the combined beds, though part of it is somewhat dirty. The Tiller contains a parting that impairs its value on Russell Fork, and thins to the north to about 30 inches on Levisa Fork. No coal was found at the horizon of the Tiller bed on Pine Mountain or in The Breaks, indicating that it thins to the northwest and perhaps also to the west from its exposures near Bucu.

Jawbone coal bed.

The Jawbone coal bed commonly lies above a coarse, quartzose, locally conglomeratic sandstone that separates it from the Tiller, the interval between the two coals being 100 feet or less. The bed takes its name from Jawbone Hollow, a tributary of Bull Run between Virginia City and Banner in the Bristol quadrangle. It has been called the Ratliff in private reports on the upper Levisa Fork drainage basin. The Jawbone is exposed in the Clintwood and Bucu quadrangles in the same localities as the Tiller and, as mentioned above, is united with the Tiller in places in the southern part of the Bucu quadrangle.

The Jawbone makes its best showing where it is united with the Tiller bed. It is probably also thick in other areas in the southwestern part of the Bucu quadrangle, as it includes $3\frac{1}{2}$ to 8 feet of somewhat impure coal in exposures on Hurricane Fork a short distance south of the area herein described. No thick coal was found at its horizon on Musick Creek, however. Along Russell Fork near Council the coal is 2 to 6 feet thick, but it thins to the north to less than 30 inches along Levisa Fork. Drill records show that it is a persistent bed in the Clintwood quadrangle and it may be minable in places. No coal was noted at the Jawbone horizon at its exposures on Pine Mountain or in The Breaks.

Garden Hole coal bed.

The Garden Hole coal is about 340 feet above the Lee formation and 140, more or less, above the Jawbone bed. The name was given it by the prospectors of the Clinchfield Coal Corporation from exposures at the Garden Hole on Russell Fork, near The Breaks. The bed is probably the same as the "so-called Imboden" of Campbell's reports on the Bristol quadrangle. It is exposed low down in the principal valleys in the southern and eastern parts of the Bucu quadrangle and along the foot of Pine Mountain.

The bed is under a ledge-making sandstone in some localities and over one in others, and this fact, combined with the presence of other coal beds not far above it, makes identification of outcrops uncertain.

The Garden Hole bed is less than 3 feet thick nearly everywhere and less than 2 feet in most places. Under and near Sandy Ridge in the vicinity of Kiser and Cane gaps it is an attractive bed 3 to 4 feet thick. It is 44 inches thick in one place at the foot of Pine Mountain, and 1 to 6 feet thick in and near The Breaks.

Aily coal bed.

There are in places several coal beds in an interval 200 feet thick above the Garden Hole bed. These beds are almost everywhere less than 2 or 3 feet thick and are thinner in most exposures. The name Aily, from a post-office on Lick Creek of Russell Fork, has been applied to what appears to be the most persistent and in most places the highest of these beds. The Aily is about 500 feet above the Lee and 160 feet above the Garden Hole coal. It appears in many of the drill records, especially those in the Clintwood quadrangle, but is only about 2 feet or less thick in most of its exposures, even in those near its type locality. It is locally minable under present conditions in small areas.

Kennedy coal bed.

A bed that lies about 600 feet above the Lee has long been known as the Kennedy or Widow Kennedy in the mining districts a short distance south of the Clintwood quadrangle. It has yielded considerable coal at shipping mines at Dante and elsewhere, but has not yielded much profit to the operators and is not now extensively mined. Some coal is shipped from it, however, from mines in the Bucu quadrangle, near Drill, on Lewis Creek. One of its most marked characteristics in the region south and west of Russell Fork is its generally crushed condition and great irregularity in thickness. In the Levisa Fork drainage basin, where it is called the Harris seam in private reports, the coal is clean and as regular in thickness as any other bed. Its characteristic sandstone bottom-rock has already been described.

The Kennedy contains a large aggregate of coal in the south half of the Clintwood quadrangle in deposits that range from a few inches to 10 feet thick within short distances. It thins to the northwest and was not found along the foot of Pine Mountain. In the Bucu quadrangle the bed

is less than 2 feet thick, except locally, in most parts of the Russell Fork and Clinch River drainage basins. Near the heads of Russell Fork and Lewis Creek, however, the Kennedy's thickness averages about 3 feet, and it is slightly more along part of Fryingpan Creek. The bed is persistent in the Levisa Fork basin, and thickens to the east from about 27 inches along Little Prater Creek to 4 or 5 feet at the east boundary of the quadrangle (fig. 3).

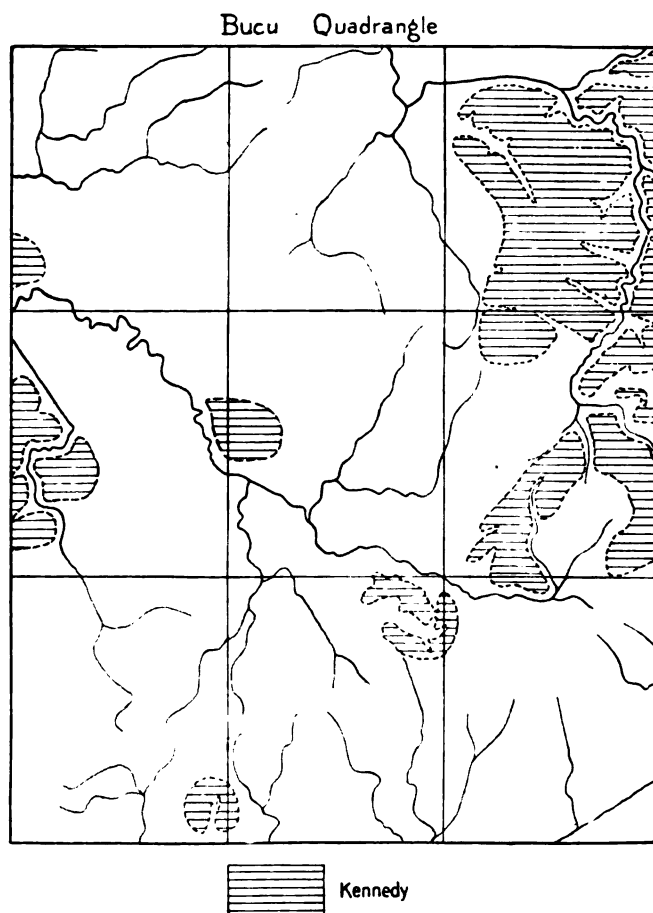


Fig. 3.—Sketch map of Bucu quadrangle, showing areas in which the Kennedy bed contains 3 feet or more of minable coal.

Lower Banner coal bed.

A bed about 200 feet above the Kennedy and 800 feet above the Lee formation is widely known as the Lower Banner in the mining districts in the general region of its type locality at Banner, on the Norfolk and Western Railway. Along upper Levisa River the same bed has been called the Cary by private investigators. This coal is extensively mined at Wilder in the Bucu quadrangle, and at Dante, a short distance south of the Clintwood quadrangle. Like the Kennedy, the Lower Banner has a sandstone bottom-rock, but it is much thinner and less conspicuous on hillsides. The strata from the Kennedy to the bottom-rock and from the Lower Banner to the Upper Banner coal are shales and thin-bedded sandstones in most places.

The Lower Banner is minable, even under present commercial conditions, in several areas. (See fig. 4.) One of the best areas is under and in the vicinity of Sandy Ridge from Coon Branch of Open Fork east to Cane Creek and the ridge east of Road Fork, where the average thickness of coal is 3 to 5 feet. Another very promising area is north of Drill, along the eastern border of the Bucu quadrangle, where the bed is about 4 to 5 feet thick. In the greater part of both areas it is exceptionally free from partings. The Lower Banner is about 3 feet thick in four small areas and 2 to 3 feet in many places. It is a very persistent bed, though locally thin, in most of the area of the quadrangles.

Upper Banner coal bed.

The Upper Banner is one of the best known and most important coal beds in southwest Virginia, and is extensively mined at Wilder, Dante, Toms Creek, and elsewhere. The mine at Wilder is in the Bucu quadrangle, and one of the largest mines near Dante and another near Toms Creek extend northward under Sandy Ridge into the Clintwood quadrangle. The average distance of the bed above the Lower Banner is 100 feet and that above the Lee formation is about 900 feet. There are shales and thin-bedded sandstones below the coal and a ledge-making, coarse-grained sandstone about 20 feet or less above it. One of the most marked characteristics of the Upper Banner is the persistent sandstone parting less than 2 inches thick in the upper half of the bed.

There are two large areas and three smaller ones in which the Upper Banner is especially attractive for mining. One of these includes the territory under and near Sandy Ridge from the southwest corner of the

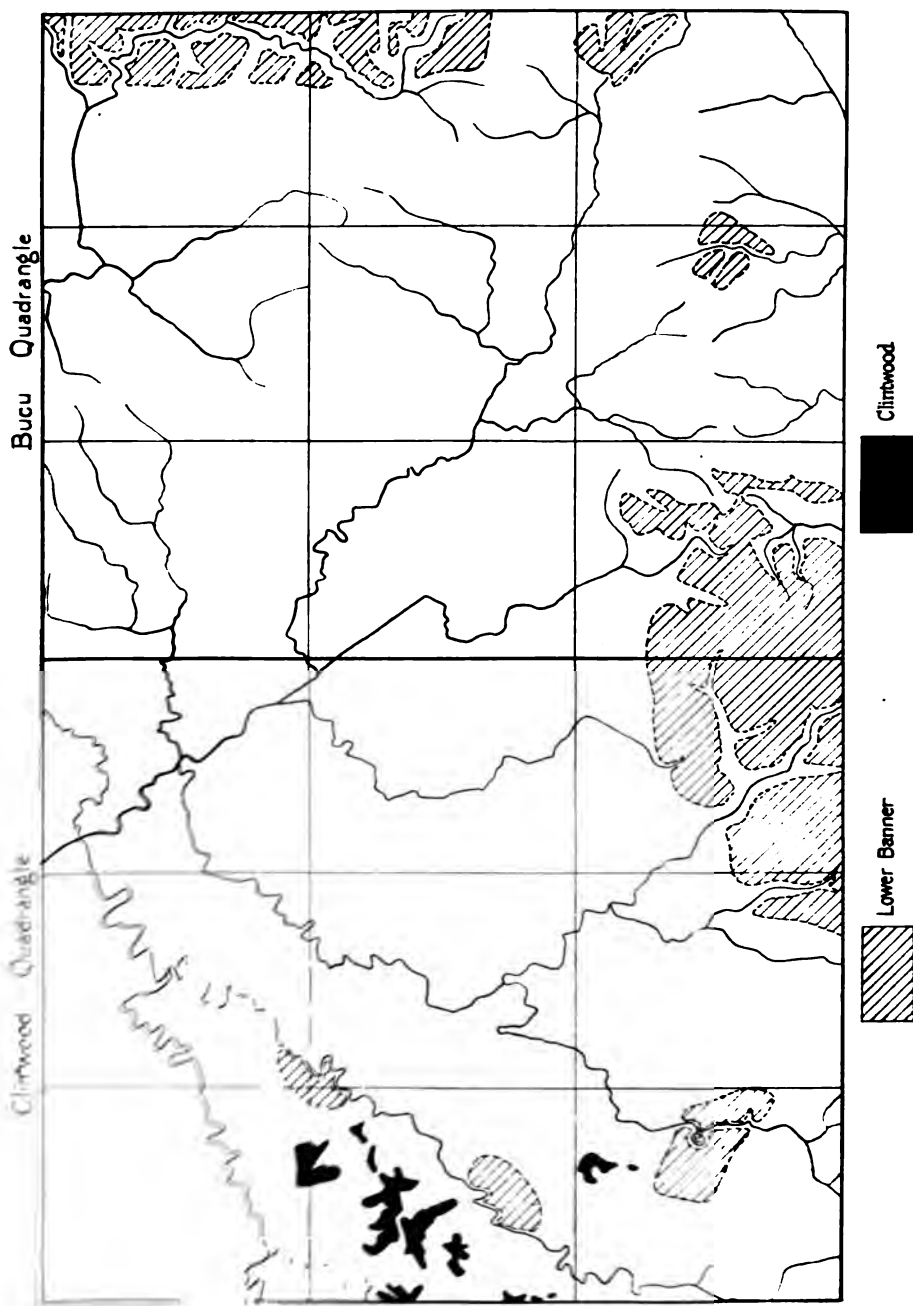


Fig. 4.—Sketch map of Clintwood and Bucu quadrangles, showing areas in which the Lower Banner and Clintwood beds contain 3 feet or more of minable coal.

quadrangle east to Road Fork, where the bed contains coal averaging 4 to 6 feet in thickness and only thin partings. Another is on both sides of McClure River north of Big Branch, extending westward to and beyond Cranesnest River and eastward to and beyond Lick Creek. In this area the average thickness of coal is 4 to 5 feet and partings are thin. In smaller areas on the west side and at the head of Fryingpan Creek the bed is in similar condition. Outside these districts, which are shown in Figure 5, the Upper Banner is split into two or three parts by a thickening of shale partings above and below the thin sandstone parting. These parts are so widely separated that they could not be mined as one bed, and commonly so close that only one could be utilized. In places one or the other of the separated parts contains 2 to 4 feet of coal. Northeast of Russell Fork all the divisions of the Upper Banner are so thin, except locally, that they can not be regarded as an important economic resource. Indeed, it is probable that coal is lacking at the Upper Banner horizon in most of the Levisa Fork drainage basin except along parts of Prater Creek.

Splash Dam coal bed.

The Splash Dam bed, so named on maps of the Clinchfield Coal Corporation because it rises from beneath Russell Fork near the splash dam, a short distance north of the mouth of Pound River, is about 70 feet above the Upper Banner bed and 970 feet above the Lee formation. It is probably the same as the Wilson bed of private investigators in the upper Levisa Fork country, though slightly lower than a bed that has been called Wilson on Prater Creek. It lies a few feet above the sandstone cap-rock of the Upper Banner, which is a conspicuous cliff-former along Levisa Fork and elsewhere. The rocks above the coal differ from place to place, being chiefly shales in some localities and coarse sandstone in others.

Coal appears at the Splash Dam horizon in many localities, but it is less than 30 inches thick in some places and is split into thin benches in many others. It makes its best showing in the southern part of the Open Fork drainage basin, where it includes 3 to 4 feet of coal. It is also thick on Lyons Fork of Cranesnest River. It is a more or less uniform bed averaging 3 or 3½ feet in thickness in the northeast corner of the Clintwood quadrangle, and is thicker farther northeast, on Bull and Poplar creeks in the Hurley quadrangle. This bed has not been thoroughly prospected and may be found to be thick in several localities where it is now unknown.

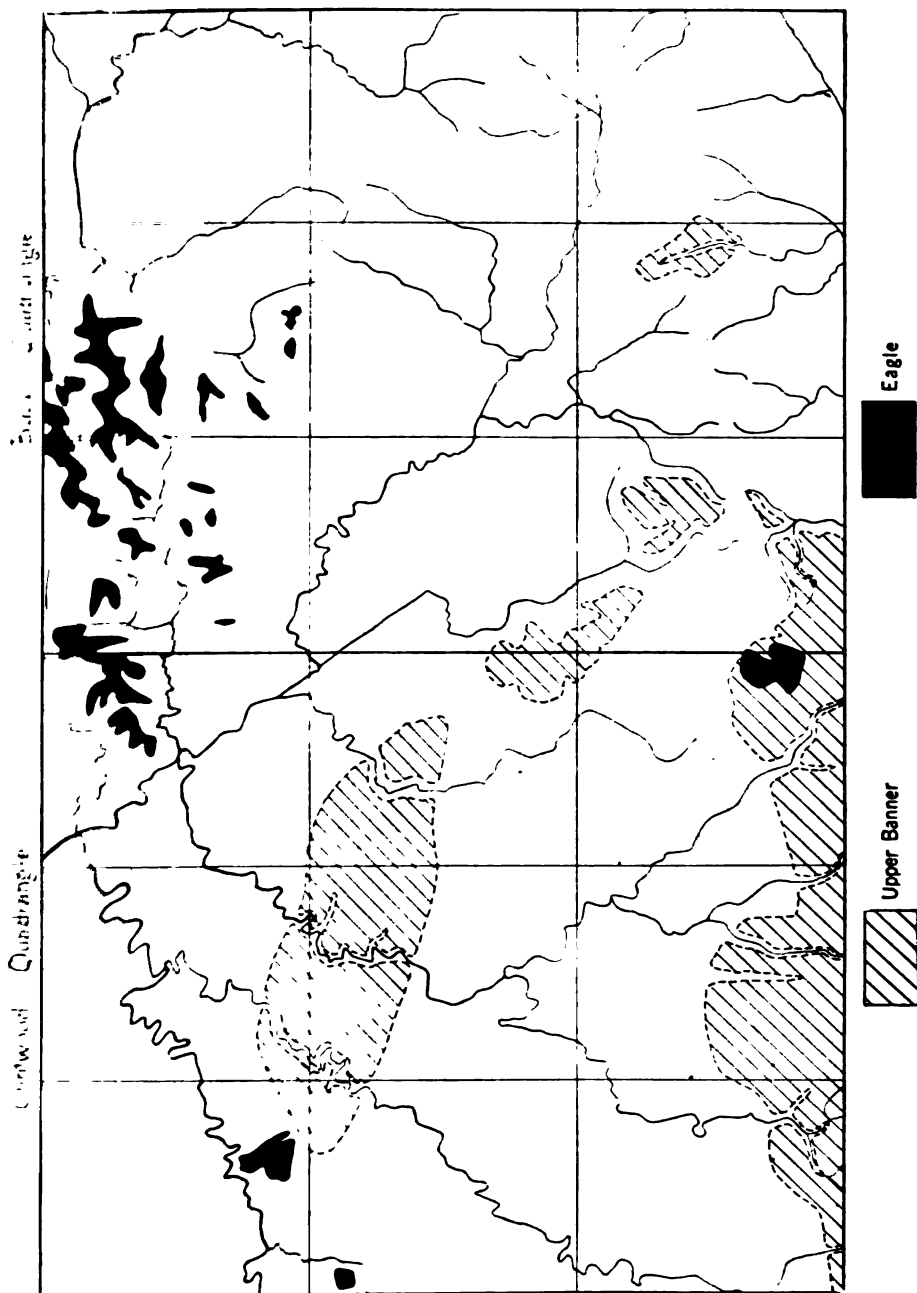


Fig. 5.—Sketch map of Clintwood and Bucu quadrangles, showing areas in which the Upper Banner and Eagle beds contain 3 feet or more of minable coal.

Hagy coal bed.

A bed here named the Hagy, from exposures near Hagy School at Leemaster and in the mine of Mr. Hagy on Trace Fork of Prater Creek, is about 100 feet above the Splash Dam and 1,070 feet above the Lee formation. Northeast of Russell Fork it commonly has a coarse sandstone bottom-rock. Its identification in the southern part of the quadrangles is somewhat uncertain, but it is probable it there lies only a few feet below the coarse sandstone that is near the top of the Norton formation. It may be the same as the Edwards bed of Campbell, which he tentatively correlates with the true Imboden seam of the Big Stone Gap coal field.

The Hagy is only about 2 feet or less thick in most places, but is 3 to $4\frac{1}{2}$ feet thick near the heads of Russell Prater Creek and its principal tributaries and near the head of Trace Fork of Prater Creek.

Glamorgan coal bed.

The Glamorgan coal, named from mines at Glamorgan in Wise County, is about 1,305 feet above the top of the Lee formation, and less than 25 feet above the Gladeville sandstone and the base of the Wise formation.

Coal is persistent at the Glamorgan horizon but it is not more than 2 feet thick in many localities. Between Clintwood and Pound River and in the northeastern and southeastern corners of the Clintwood quadrangle and adjacent parts of the Bucu, the aggregate thickness of coal layers is 2 to 4 feet, but one or more detrimental shale partings are also commonly present.

Lyons coal bed.

A bed that is about 60 feet above the Glamorgan in the southwestern part of the Clintwood quadrangle is here named the Lyons, from a post-office on Big Ridge. It is separated from the Glamorgan by shale in most places and, in the Clintwood quadrangle, lies under a rather thin but conspicuous white sandstone that has already been mentioned. In places the Lyons and Glamorgan are so close that it is difficult to distinguish the former from a split off the latter. The Lyons is too thin, except in a very few small areas, to be mined on a large scale, but can be utilized for local fuel supplies.

Blair coal bed.

The Blair bed, so named by Butts from exposures on the Blair property on Indian Creek, Wise County, is about 80 feet above the Glamorgan, and is

separated from the Lyons seam chiefly by the white sandstone cap-rock of the latter. Locally in and near the northeast corner of the Clintwood quadrangle the Blair is in two benches, separated by 30 feet or less of shale. The bed contains 2 to 3 feet of coal in the Clintwood district, $1\frac{1}{2}$ to $5\frac{1}{2}$ feet in the Russell Prater Creek drainage basin and adjacent areas, and probably less elsewhere. Nearly everywhere, however, there are several shale partings interbedded with the coal.

Eagle coal bed.

A coal bed that lies about 125 feet above the Glamorgan seam has been traced to War Eagle, W. Va., where it is locally called the Middle War Eagle. This bed has been correlated with the Eagle coal of Fayette County, West Virginia, by the West Virginia Geological Survey, and the name Eagle is used here. The bed is overlain by coarse gray sandstone that makes conspicuous cliffs from Russell Fork northeast into Kentucky and West Virginia, making one of the best stratigraphic markers in the entire Pottsville group. The sandstone thins between Russell Fork and Clintwood, but may still be identified near the county seat. One of the peculiarities of the Eagle near Russell Prater and Barts Lick creeks is a local development of a thin sandstone parting, almost identical in appearance with the one that is characteristic of the Upper Banner bed.

The Eagle includes thick coal deposits that underlie only rather small areas near the ridge tops (see fig. 5). In the northwestern part of the Bucu quadrangle and adjoining parts of the Clintwood quadrangle the average thickness of coal is 4 to 5 feet. It is about the same on and near Flat Spur and nearly as thick in small areas near Clintwood, but is thinner elsewhere.

Clintwood coal bed.

The Clintwood bed is 200 feet above the Glamorgan and only a few feet above the sandstone cap-rock of the Eagle bed. In most of the region it is overlain by nearly 200 feet of shale and inconspicuous fine-grained sandstone, but along the western border it has a thin but conspicuous white sandstone cap-rock.

The Clintwood is a remarkably thick bed just west of the central part of the Clintwood quadrangle, and contains 4 to 11 feet of coal in small areas near Clintwood and Darwin and an outlier on Big Ridge (see fig. 4). The bed thins north and northeast of Clintwood. The horizon of the Clintwood was found on Flat Spur and high in the ridges in the northwestern

part of the Bucu quadrangle, but no coal was seen. As coal is present and fairly thick in the Hurley quadrangle, a short distance north of the Bucu, it is probable that it extends southward into the latter area.

Campbell Creek coal bed.

The Campbell Creek bed derives its name from exposures in Kanawha County, West Virginia, and has been traced to the Virginia boundary on Tug Fork by the West Virginia Geological Survey, and thence into the Bucu quadrangle by the writer. It is about 270 feet above the Clintwood bed and lies between thick beds of medium-grained sandstone. It was called the Lower Bolling coal by Butts in the Pound quadrangle and, as mentioned in the description of correlations with adjoining areas, is known under several names in Pike County, Kentucky. In the Virginia portion of these quadrangles, the bed has been removed by erosion from all but a few small outliers on high ridges near Clintwood and the heads of Russell Prater Creek. No coal was found but some is probably present, as the horizon is productive in the Kentucky portion of the Clintwood quadrangle, and in neighboring parts of the Pound and Hurley quadrangles.

DETAILED DESCRIPTION OF COAL BEDS.

Method of statement.

In this region the construction of railroads and exploitation of coal resources will necessarily be planned with special reference to the positions of the principal valleys, as well as to the location of the thickest and most widespread coal deposits. It has been deemed advisable, therefore, to treat each of the principal drainage basins separately. Each coal bed in each of these basins is described separately, beginning with the lowest, and its outcrop is traced along one side of the major stream, including tributaries on that side, and back along the other side. A brief summary of the stratigraphy, structure, and principal coal resources of each basin is given in a geologic outline, and summaries of the principal points of interest concerning each coal bed are given at the beginning of the description of that bed.

A number is given to each measured coal exposure and its location shown on both the geologic and topographic maps. Since the numbers are assigned in the order in which the exposure is mentioned in the text, it is

easy to refer from the maps to the written descriptions. Unless otherwise stated, all measurements were made by the writer or his assistants.

The elevations given are not all of the same degree of accuracy and so certain symbols are used to show the method by which they were obtained. Those marked B. were taken with an aneroid barometer and may be subject to correction. Those with an S. were determined by J. I. Gayetty with stadia, and those with C. C. C. are on transit lines of the Clinchfield Coal Corporation. The symbol H. L. indicates that an elevation was obtained by hand-leveling from neighboring stadia or transit stations.

Many measurements of coal more than 30 inches thick are shown in graphic sections and also described in the text. The numbers at the sides of the graphic sections indicate thicknesses in inches, those on the right being for layers of coal, and those on the left for partings that would be discarded in mining.

Russell Fork drainage basin.

POUND RIVER AND TRIBUTARIES OTHER THAN CRANESNEST RIVER.

Geologic outline.—Pound River flows along or near the axis of the Middlesboro syncline, so that the strata dip toward it from both sides. This dip is gentle on the south side of the river and also on the north side for a short distance from the main valley, but it increases gradually toward the crest of Pine Mountain, where it is 33 degrees to the southeast. Beds which lie far below Pound River rise so as to reach the surface far up the mountain slopes, and Mississippian and Devonian strata form the upper part of the mountain on the Kentucky side and have there been thrust up over the Wise formation along the great Pine Mountain fault.

The lowest formation exposed in the Virginia part of the Clintwood quadrangle is the Pennington shale, which caps Pine Mountain west of Blowing Rock Gap. The next higher formation is the Lee, which caps the mountain east of Blowing Rock Gap, and everywhere outcrops near the mountain top on the Virginia slopes. The most conspicuous members of the Lee are massive conglomeratic sandstones.

The Norton formation outcrops near the foot of Pine Mountain and also in the valley of Pound River as far up as Laurel and Jerry branches, in most of the area on each side of the lower part of the river, and in a small inlier on Georges Fork. The lower part of the formation is exposed only on the mountain slopes, where the Kennedy bottom-rock is a massive quartzose conglomeratic sandstone similar to the Lee and, like the Lee.

making dip slopes and small hogbacks facing the mountain crest. There are 200 or more feet of shales and inconspicuous sandstones between the Kennedy bottom-rock and the Lee, but outcrops are poor. The upper part of the Norton, however, is well exposed along and near the lower part of Pound River.

The Gladeville sandstone and Wise formation appear only on the ridge tops on each side of the lower part of Pound River, but farther upstream the Gladeville is low down in the valley and Wise outcrops are more extensive. The Gladeville is commonly slightly less than 100 feet thick, brownish, crumbly or fairly compact, and massive, though it contains some shaly layers in a few localities and is nowhere a particularly good stratigraphic marker. The maximum thickness of Wise present is about 575 feet, the upper 300 feet being poorly exposed, present in only a few places, and apparently containing considerable shale. The most easily identified stratum is a thin but very resistant white siliceous sandstone that lies about 60 feet above the base of the Wise.

The stratigraphic succession of the coal-bearing formations is shown by the generalized section of the north third of the Clintwood quadrangle (Pl. IV), by several drill records (Pl. II), and by local sections 1, 2, and 3.

Part of the area drained by Pound River and its tributaries other than Cranesnest River is not particularly rich in coal resources. The Pennington is practically barren and no workable coal was found in outcrops of the Lee. Prospecting in the Norton and higher formations north of Pound River is said by the people living in that vicinity to have revealed no beds much thicker than 3 feet, and the best measurement obtained during the recent geologic survey showed only 44 inches of dirty coal. Outcrops are very poor, however, and prospecting has not been thorough, so it is possible that better results may reward further search, especially in the Wise formation.

South of Pound River, no coal as much as 3 feet thick was found east of Rocky Branch, and the Upper Banner bed, though thick on lower Cranesnest River, appears to be thin elsewhere in the Pound River drainage basin. No coal was found at the Lower Banner or Kennedy horizons, though they are probably not barren everywhere. Considerable coal has been found in the Wise formation as the result of thorough prospecting of the Clintwood and associated beds between Pound and Cranesnest rivers. There are five coal beds in the lower 200 feet of the Wise that are fairly persistent and contain from 2 to 4 feet of coal, though the average for any one of them is not more than 3 feet. (See figs. 4, 5, and 6.) The Campbell Creek coal, which is a double bed nearly 300 feet above the base of the Wise, contains

workable coal a few miles west of the Clintwood quadrangle, and may eventually be found near the tops of a few knobs bordering Georges Fork and Brush Creek.

Garden Hole coal bed.—The lowest bed of commercial importance found near Pine Mountain is the Garden Hole, which lies 400 to 500 feet below

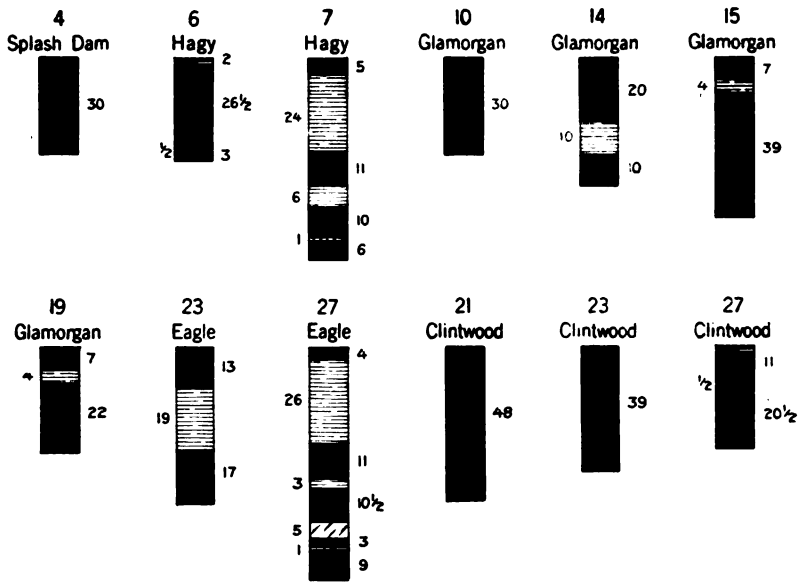


Fig. 6.—Sections of coal beds in the Pound River drainage basin.

the Upper Banner coal horizon and a few feet below the thick conglomeratic sandstone that forms a low hogback at the foot of Pine Mountain. The Garden Hole is an impure and fractured bed 44 inches thick where Skeet Rock Branch crosses the wagon road a quarter of a mile north of the Clintwood quadrangle, and may outcrop in a few places farther southwest, north of the line mapped as the Kennedy horizon.

Upper Banner coal bed.—The Upper Banner bed, which lies 210 to 300 feet above the Kennedy horizon, is represented only by road blooms of an apparently thin coal, except, possibly, at one place on Cane Creek, where the following is tentatively correlated with that bed:

Section of Upper Banner (?) coal bed on Cane Creek, half a mile north of Huckleberry.

(Location 1, elevation 1,550 B.)		
	Ft.	in.
Sandstone.		
Coal		7
Shale	2	6
Coal		6
Sandstone		1
Coal, with 5 inches cannel near top, bottom not seen.....	1	9+
Coal	2	3+
Partings		1

Splash Dam coal bed.—The Splash Dam horizon averages 60 feet above the Upper Banner and overlies the fairly coarse sandstone that forms the cap-rock of the latter bed. Coal blossoms in roads were noticed in a number of places, and measurements were obtained in three openings. The only exposure found north of Pound River is near Cane Creek and the road from that stream to Huckleberry (location 2, elevation 1,453 H. L.), where the bed is 18 inches thick, and what is probably another bench of that bed is 8 inches thick a short distance down the creek. South of the lower part of Pound River the Splash Dam contains 30 inches of hard, bright coal under a roof of firm shale at two places on Cane Branch,—one a small local mine 200 yards north of the road crossing (location 3, elevation 1,492 H. L.), and the other an opening on the north fork (location 4).

Hagy coal bed.—The Hagy coal bed lies above a sandstone that is not quite so good a ledge-maker as the one under the Splash Dam horizon, and is about 150 feet above the Upper Banner horizon. Blooms of this bed appear in most of the roads that cross its horizon in the lower part of the Pound River drainage basin, but no full measurements were obtained. The Hagy is 20 inches thick in a hollow three-quarters of a mile south of Skeet Rock (location 5, elevation 1,525 B.). The same bed is 32 inches thick at an exposure $1\frac{1}{4}$ miles south of Skeet Rock, near Pound River (location 6, elevation 1,460 B.), the upper 2 inches being bony. Northwest of Skeet Rock the bed is as follows:

Section of Hagy coal bed half a mile northwest of Skeet Rock.

(Location 7, elevation 1,710 B.)		
	Ft.	in.
Sandstone, shaly.		
Coal, cannel at top.....		5
Shale	2	
Coal		11
Shale		6
Coal		10
Sandstone, shaly		1
Coal		6
Coal	2	3
Partings		7

Two measurements were taken on Laurel Branch, north of Isom, on coal that is either at the Hagy horizon or near it; one, on the right-hand fork (location 8, elevation 1,580 B.), is about 30 inches, and the other, on the left-hand fork (location 9, elevation 1,640 B.), is 20 inches.

Glamorgan and Lyons coal beds.—The Glamorgan bed appears to be persistent in this area, though rarely more than 30 inches thick. It is 320 to 400 feet above the Upper Banner horizon and 15 feet or less above the base of the Wise formation, so that its outcrop is practically the same as that of the top of the Gladeville sandstone. The Lyons coal is not commonly workable, lies 20 to 60 feet above the Glamorgan in many places, and can be easily identified by means of the white siliceous sandstone which lies a short distance above it.

At four openings east (location 10) and south (locations 11, 12, and 13) of Skeet Rock, the Glamorgan is 26 to 30 inches thick and lies near the tops of rather broad spurs. The roof is commonly a drab sandy shale containing fossil plants. Farther west, in the vicinity of Isom, the Glamorgan includes one or more shale partings and on the road leading west from Laurel Branch (location 14, elevation 1,645 B.) shows 30 inches of coal with 10 inches of clay 10 inches from the bottom. The floor is a few feet of sandy clay or shale resting on sandstone.

The Glamorgan is exceptionally thick at an opening measured by Butts near Freeling, on Howell Branch of Georges Fork:

Section of Glamorgan coal bed near Freeling.

(Location 15, elevation 1,510 B.)

	Ft.	in.
Coal		7
Clay		4
Coal	3	3
Coal	3	10
Parting		4

The Lyons coal was not measured on Georges Fork, but blooms of the Glamorgan appear low in the valley for a considerable distance upstream. The Glamorgan is 28 inches thick on the new road $1\frac{1}{2}$ miles west of Clintwood (location 16, elevation 1,694 S.).

Near Brush Creek School (location 17, elevation 1,570 B.) the Glamorgan is in two benches as at Freeling, but the lower bench is only 18 to 21 inches thick and the clay parting is 7 to 10 inches thick. A bed measured by W. A. Nelson near the mouth of Brush Creek is probably the Lyons:

Section of Lyons (?) coal bed northeast of the mouth of Brush Creek.

(Location 18, elevation 1,570 B.)

	Ft.	in.
Coal, impure at top.....		9
Shale	4	10
Coal, with half an inch of clay near base.....	2	
Clay and shale, with coal streak near top.....	3	
Coal	1	

The Glamorgan and Lyons coal beds lie near the top of the Pound-Cranesnest divide east of Rocky Branch and both beds form several blooms on the ridge road. The Lyons is probably thin. The Glamorgan is reported to be about 2 feet thick at several places, and the following measurement is remarkably similar to the one near Brush Creek School:

Section of Glamorgan coal bed near Anderson School.

(Location 19, elevation 1,750 B.)

	Ft.	in.
Coal		7
Shale		4
Coal	1	10
Coal	2	5
Parting		4

The two beds also lie near the top of the divide south of the lower part of Pound River and show in the ridge roads east from the mouth of Cranesnest River. In this district both the Glamorgan and Lyons are less than 2 feet thick.

Blair coal bed.—The Blair bed lies 10 to 20 feet above the white siliceous sandstone that makes the first conspicuous ledge above the Lyons coal, and averages about 80 feet above the base of the Wise formation. The divide between Pound and McClure rivers is too low to contain this bed and it occurs north of Pound River only near the spur tops west of Cane Creek and near the Pound. Between Pound and Cranesnest rivers its area is more extensive. An opening measured by Nelson 1 mile northwest of Clintwood (location 20) on what may be the Blair shows a bed 27 inches thick, including two thin partings. Full measurements were not made elsewhere on Georges Fork, Brush Creek, and Jerry Branch, but the bed is reported to be about 30 inches thick at the few places it shows. A few road blooms seemed to indicate a thickness of only about 1 foot and it is possible the bed thins locally.

Eagle and Clintwood coal beds.—The Eagle bed lies about 90 feet above the Blair, and the Clintwood bed is 20 to 50 feet higher—about 200 feet above the base of the Wise formation and 510 to 610 feet above the Upper Banner horizon. As indicated by the Clintwood outcrop on the accompanying geologic map, these beds underlie only small areas in the Clintwood quadrangle, except near Georges Fork, and in most places outcrop well up in the hills. The Clintwood is a very thick and valuable bed in small outliers south of Clintwood and in a larger area west of the quadrangle on Georges and Lick forks; but it thins notably to the northeast and north, and is less than 4 feet thick on Jerry Branch, Brush Creek, and the lower part of Georges Fork. The Eagle bed contains 2 to 4 feet of coal in addition to clay partings that impair its value. It is commonly considered by prospectors to be the lower bench of the Clintwood, and it may be that the two beds unite in places.

The Clintwood bed of this area is at its best near the head of Laurel Creek of Georges Fork. There are 4 feet of clean coal at a small mine $1\frac{1}{2}$ miles southwest of Clintwood (location 21, elevation 1,975 C. C. C.), and openings on Cranesnest River drainage in this and neighboring outliers of the same bed make an even better showing. The Eagle bed is 19 inches thick and is separated from the Clintwood by 20 feet of shale.

The Clintwood is only 22 inches thick on a tributary of Brush Creek 1 mile northwest of Clintwood (location 22), but is thicker a short distance east, as shown in the following measurement by Nelson:

Sections of Eagle and Clintwood coal beds near head of Brush Creek.

(Location 23, elevation 1,810 B.)

Shale.		Ft.	in.
Coal (Clintwood)	.....	3	3
Interval, chiefly shale	.....	20	
Coal	} (Eagle)	1	1
Clay		1	7
Coal		1	5

A pit half a mile east of Brush Creek School (location 24) shows the Eagle to be essentially the same as at location 23, and it is not much different at a small mine near the school (location 25), though the clay parting is there only 9 inches thick and the coal below it is somewhat thicker than at the other places. The measurement of the Eagle given below was made at a small mine half a mile southeast of the mouth of Brush Creek. The bed is the same half a mile north (location 27), and the Clintwood is about 35 feet above it in that locality and about 32 inches thick.

Section of Eagle coal bed near mouth of Brush Creek.

(Location 26, elevation 1,720 B.)

	Ft.	in.
Sandstone.		
Coal	1	
Shale, coal, and pyrite.		3
Coal		10
Bone		1
Coal	1	
Shale		10
Coal	1	
Coal	3	10
Partings	1	2

Near the head of a small branch three-quarters of a mile northwest of Dwale (location 28, elevation 1,860 C. C. C.), there are pits on two benches of the Clintwood coal, one 15 feet above the other. The upper bench contains coal about 2 feet thick and the lower a bed that is slightly thicker but contains several shale partings.

CRANESNEST RIVER.

Geologic outline.—The Cranesnest River drainage basin in the Clintwood quadrangle includes a long narrow strip from 1½ to 6 miles wide extending from the mouth of the river to the southwest corner of the quadrangle. A gentle northwesterly dip prevails throughout the area and is such that about the same beds are exposed in all of the river valley, the downstream component of the dip being nearly the same as the river gradient.

The lowest beds exposed lie a short distance above the Kennedy coal horizon, the upper part of the Norton formation is exposed in all of the main valleys, and the Gladeville sandstone and the lower part of the Wise formation cap nearly all of the main ridges bounding the sides of the basin. The highest beds present are near the horizon of the Campbell Creek coal. The characteristics of the formations are shown by the generalized columnar sections for the Clintwood quadrangle (Pl. IV), by a number of drill records (Pl. II), and by local sections 2, 3, 4, 5, and 6. The intervals between coal and other beds decrease, in general, from south to north, so that maximum intervals given in the following pages apply to the southern part of the basin and minimum intervals to the northern part. There are no reliable stratigraphic markers except the Upper Banner coal

bed, which has a characteristic sandstone parting. The Gladeville sandstone and the white sandstone near the base of the Wise are useful aids to correlation.

The Cranesnest drainage basin contains coal at sixteen or more horizons, with a thickness of more than 2 feet in parts of eight or nine beds. (See figs. 4, 5, and 7.) The bed that promises most for future development is the Upper Banner between Long and Tarpon branches, where it contains an average of about 4 feet of coal along the outcrop, and is evidently thick under Big Ridge on the east and perhaps also under part of the Pound-Cranesnest divide on the west. The same bed is nearly as thick along Trace Fork. The thickest coal bed in the area is the Clintwood south and southwest of the town of Clintwood, where it is locally 9 feet or more thick, exclusive of partings. Other coal beds, as well as the Upper Banner and Clintwood outside the areas mentioned, are commonly less than 3 feet thick.

Lower Banner coal bed.—The Lower Banner bed outcrops a short distance above water level from the mouth of the river nearly to its head, except in two small areas where it is below drainage. It lies 40 to 100 feet below the Upper Banner horizon, the distance in most places being close to 100 feet, and 170 to 245 feet above the Kennedy horizon. The bed contains one to nearly four feet of coal.

The Lower Banner was reported to be 41 inches thick, including 5 inches of clay, near the mouth of Bartley Branch, but the first measurement obtained on the west side of the river above its mouth was a little south of the mouth of Holly Creek (under location 40, elevation 1,458 H. L.), where the bed is 37 inches thick and apparently clean. At the mouth of Long Branch (location 29, elevation 1,465 H. L.) the Lower Banner is only 20 inches thick and lies 87 feet below a pit on the Upper Banner. No measurements of the Lower Banner coal were obtained south of Honeycamp Branch, on either Cranesnest River or its tributaries, though the bed was reported to be more than 3 feet thick in an opening near the head of Ellis (Alleys) Creek and in another on Buck Branch.

The Lower Banner was measured at several places on the east side of the river. Just below the mouth of Honeycamp Branch (location 30, elevation 1,505 B.) it contains 36 inches of coal and $21\frac{1}{2}$ inches of clay near the middle. On Camp Creek (location 31, elevation 1,560 B.) the bed consists of 27 inches of coal and 8 inches of carbonaceous shale 8 inches from the bottom. Between Camp Creek and Big Branch (location 32, elevation 1,465 B.) the Lower Banner is 35 inches thick, including three thin partings of "rash." Between Big and Lick branches (location 33)

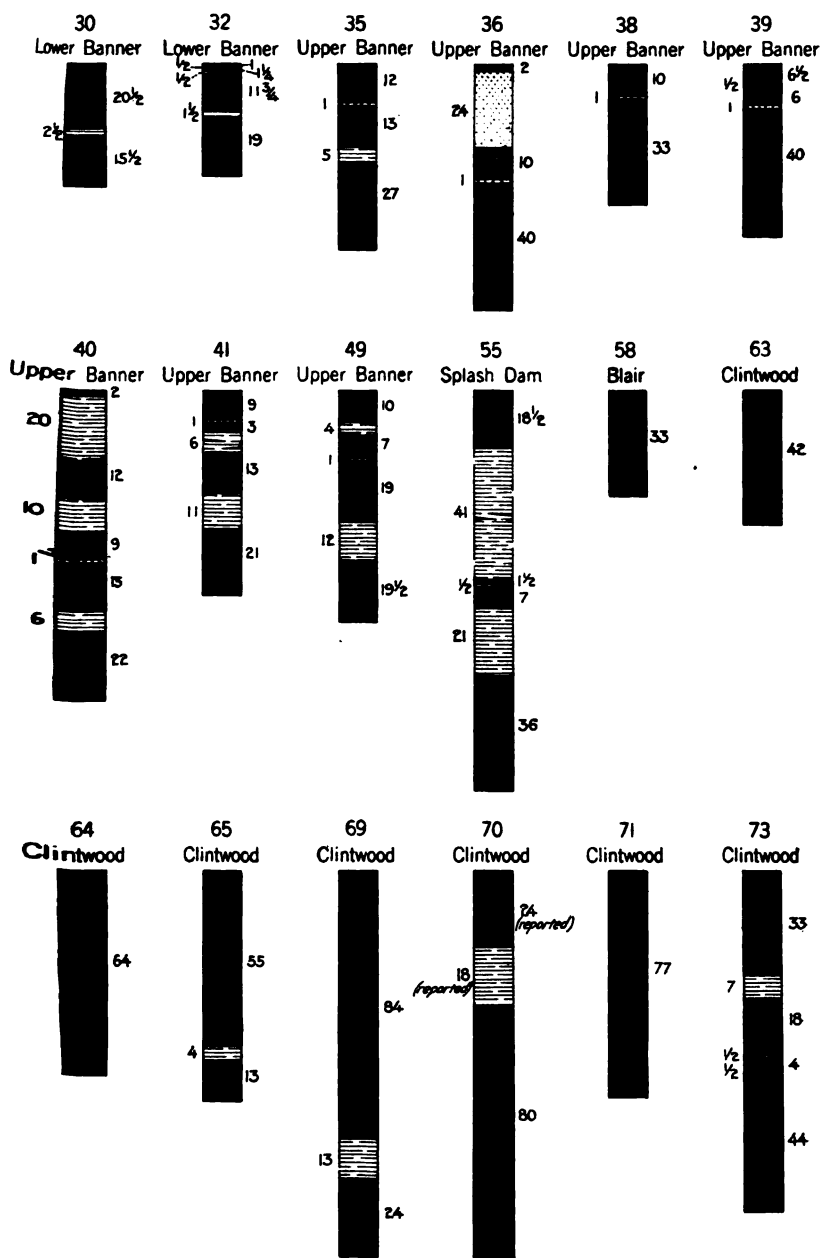


Fig. 7.—Sections of coal beds in the Cranesnest River drainage basin.

there are 32 inches of coal and 3 inches of clay near the middle of the bed. Near Poplar Branch (location 34, elevation 1,430 B.) the bed is poorly exposed, but contains a 3-inch clay parting 15 inches below the top and at least 21 inches of coal. In nearly all these openings the roof is shale or shaly sandstone and the floor a hard clay or shale.

Upper Banner coal bed.—The Upper Banner bed lies, in this area, 850 to 1,030 feet above the base of the Norton formation and 330 to 470 feet below the top of the Gladeville sandstone, the intervals increasing to the south. The coal bed outcrops low down in the valley of Cranesnest River from its mouth to its head-waters, and extends a short distance up the western tributaries and farther up the eastern tributaries. A massive sandstone which is about 30 feet thick in most areas and lies 5 to 20 feet above the Upper Banner is a useful marker for the latter, and the characteristic thin sandstone parting also serves to identify the coal in most, but not all, of its exposures. The thickest exposures of coal, averaging about 4 feet, are along and near Cranesnest River between Tarpon and Long branches and near Keel Branch. The bed was found at only a few places south of Camp Branch, and is apparently thin and perhaps split into two or more beds, except on Trace and Steele forks, where it is $1\frac{1}{2}$ to 4 feet thick.

No coal was found at the Upper Banner horizon near the mouth of Cranesnest River and the first measurement obtained on the west side of the valley was $2\frac{1}{4}$ miles south of the mouth:

Section of Upper Banner coal bed on Cranesnest River, two and one-half miles south of its mouth.

(Location 35, elevation 1,550 B.)

Sandstone.	Ft.	in.
Coal	1	
Sandstone		1
Coal	1	1
Shale		5
Coal	2	3
Coal	4	4
Partings		6

Half a mile up the valley Stone noted that the shale parting is lacking, the coal below the sandstone parting being 37 inches thick and that above at 12 inches; in the next tributary from the north (location 36, elevation 1,477 C. C. C.) the section is the same except that the lower coal is 40 inches thick and the upper coal 10 inches. Two exposures on Bartley Branch are as follows:

Sections of Upper Banner coal bed on Bartley Branch.

(Location 37, elevation 1,486 C. C. C.)		(Location 38, elevation 1,450 B.)	
	Ft. in.		Ft. in.
Coal	3	Sandstone	
Sandstone	10	Coal	10
Coal	5	Sandstone	1
Shale	1	Coal	2 9
Coal	7	Coal	3 7
Sandstone	1/2	Parting	1
Coal	2 3		
Coal	3 6		
Partings	11 1/2		

Stone found that the Upper Banner a short distance south of the mouth of Bartley Branch (location 39, elevation 1,526 C. C. C.) consists of 40 inches of coal below the sandstone parting and 12 1/2 inches above it, and that half a mile farther up Cranesnest River there are 32 inches in the lower part and 17 inches in the upper; at both places there is a thin shale parting in the upper part of the bed. He gives the thickness of the bed on Holly Creek as 40 1/2 inches, including 1 1/2 inches of sandstone. Two measurements by Harnsberger between Holly Creek and Long Branch follow:

Sections of Upper Banner coal bed on Cranesnest River between Holly Creek and Long Branch.

(Location 40, elevation 1,550 C. C. C.)		(Location 41, elevation 1,593 C. C. C.)	
	Ft. in.		Ft. in.
Coal	2	Sandstone	
Shale	1 8	Coal	9
Coal	1	Sandstone	1
Shale	10	Coal	3
Coal	9	Bone and shale	6
Sandstone	1	Coal	1 1
Coal	1 3	Shale	11
Shale	6	Coal	1 9
Coal	1 10	Coal	3 10
Coal	4 10	Partings	1 6
Partings	1 5		

At the mouth of Long Branch (location 42, elevation 1,564 C. C. C.), the Upper Banner consists only of 2 inches of coal at the top and 28 inches at the bottom, with 5 inches of clay between; the roof is 7 feet or more of shale, so that it is evident that the upper part of the bed shown in preceding sections was either never deposited or lies more than 7 feet above the lower part.

The Upper Banner was not seen in the Cranesnest River drainage basin above the mouth of Camp Creek except between Keel and Honeycamp branches and on Steele, Trace, and Lyons forks. The part of this area in which the bed was not found has not been thoroughly prospected, but it is thought that little thick coal is present in most of it.

Stone cites several openings on the west side of Steele Fork, just outside the Clintwood quadrangle, that show the Upper Banner to contain 17 to 40 inches of coal and only thin partings, and one pit at which there is 44 inches of coal and two shale partings aggregating 63 inches. In the extreme southwest corner of the Clintwood quadrangle, on the east side of Steele Fork, the Upper Banner consists of 44 inches of coal, 1 inch of sandstone, and 7 inches of shale near the top.

Near the head of Trace Fork, south of the Clintwood quadrangle, the Upper Banner is nearly 3 feet thick. At John Lodge's house, $1\frac{3}{4}$ miles above the mouth of the fork, the bed, according to Stone, is 35 inches thick on the west side of the valley and 26 inches on the east side, including 1 inch of sandstone near the middle. Stone states that the bed is 27 inches thick at Harrison Adkins's (location 43 ?), and that a quarter of a mile farther downstream an additional 21 inches of coal was found, separated from the 27-inch lower bench by 11 inches of clay and coal. Across the ridge to the north, on the south side of Lyons Fork near its mouth (location 44), Nelson visited an opening which is tentatively correlated with the Upper Banner and which was reported to be 84 inches thick, including 14 inches of shale. This exceptional thickness, if accurately reported, is probably local, as it has not been found elsewhere in this part of the basin. The bed is less than 2 feet thick at the head of Lyons Fork.

On the east side of Cranesnest River, between the mouths of Honeycamp and Keel branches, Stone cites the two measurements on the Upper Banner given below. The locations on the maps are only approximate, as the openings could not be found by the writer. The occurrence of such thick coal in this locality is rather surprising and is probably only a local feature.

Sections of Upper Banner coal bed on Cranesnest River near Keel Branch.¹

(Location 45.)			(Location 46.)		
Shale.	Ft.	in.	Shale	Ft.	in.
Coal		10 ½	Coal		10
Shale		8	Shale		4
Coal		6 ½	Coal		6 ½
Sandstone		1 ½	Sandstone		1 ½
Coal	1	5	Coal	1	6
Shale		½	Clay		10
Coal	1	8 ½	Coal	1	9 ½
Coal	4	6 ½	Coal	4	8
Partings		10	Partings	1	3 ½

The bloom of the Upper Banner coal may be seen at several places on the new road up Camp Creek, and the full thickness of a bed that is directly overlain by the sandstone cap-rock (location 47, elevation 1,635 B.) is 21 inches; there is coal bloom at an horizon about 20 feet lower, however, so that it is probable that the bed is split into two parts, the lower part being the same as that measured at the mouth of Long Branch (location 42). A short distance down the Cranesnest the bed makes a better showing, and the following sections indicate its character on both sides of the mouth of Big Branch:

Sections of Upper Banner coal bed on Cranesnest River near Big Branch.

(Location 48, elevation 1,570 B.)			(Location 49, elevation 1,590 C. C. C.)		
Sandstone.	Ft.	in.		Ft.	in.
Coal		½-3	Shale, under sand-		
Shale	2	3	stone		5
Coal		9	Coal		10
Sandstone		½	Shale		4
Coal	1	1	Coal		7
Shale, carbonaceous...		1	Sandstone		1
Coal	2	3	Coal	1	7
Shale.			Shale	1	
Coal	4	1	Coal	1	7 ½
Partings		1 ½			
			Coal	4	7 ½
			Partings	1	5

The Upper Banner east of the river is a thick bed with little waste in partings nearly as far north as Tarpon Branch. On Tarpon, however, it is so split by shale that it is of comparatively little value, and farther north it appears to be an unimportant bed.

¹ Stone, R. W., Coal resources of the Russell Fork basin in Kentucky and Virginia: U. S. Geol. Survey Bull. 348, p. 110, 1908.

Section of Upper Banner coal bed on Tarpon Branch.

(Location 50, elevation 1,609 C. C. C.)

	Ft.	in.
Coal		$\frac{1}{2}$
Shale		$\frac{1}{2}$
Coal	2	
Sandstone		$\frac{3}{4}$
Coal	9	
Clay	3	
Coal	4	
Shale	7	2
Coal		2
Clay		1
Coal	1	7
Coal	3	$\frac{1}{2}$
Partings	7	$7\frac{1}{4}$

Splash Dam and higher coal beds in Norton formation.—Coal outcrops at nine or more horizons between the Upper Banner coal horizon and the Gladeville sandstone, but there are only a few localities where any of the exposures show more than 2 feet of coal in any one bed. A typical example may be seen on Lick Fork a few rods east of the quadrangle boundary, where seven coal beds, all less than 14 inches thick, were measured in a vertical interval of 150 feet above the Upper Banner horizon. There are only three beds that can be regarded as at all persistent or important. The Splash Dam bed, which lies just above the sandstone forming the Upper Banner cap-rock and is 50 to 80 feet above the Upper Banner, contains more than 3 feet of coal on Lyons Fork and more than 2 feet in several localities. The Haggy bed is 120 to 180 feet above the Upper Banner, and has a maximum thickness of 30 inches. A bed lying just above a coarse sandstone and 180 to 250 feet above the Upper Banner horizon contains 2 feet or less of coal in some exposures.

No complete measurements were obtained on any of the beds in this interval in the lower part of the Cranesnest River basin, but there are a number of road blooms and a few caved pits, especially at the Splash Dam and Haggy horizons. There are probably at least 2 feet of coal in the Splash Dam and Haggy beds in part of this area. On the new Clintwood road up Long Branch and Camp Creek, the Splash Dam appears to be in two or three very thin benches and the Haggy is also thin. A higher bed is 21 inches thick on Long Branch (location 51, elevation 1,680 B.), including 1 inch of shale near its base, and is 24 inches thick in a pit at the mouth of that stream. The Haggy bed is reported as 30 inches thick on Lick Branch near Darwin (location 52, elevation 1,585 B.), and a higher bed as 18 inches thick in a small hollow by the store.

South of Foraker the Splash Dam has been opened at several places and is locally fairly thick. An opening measured by Nelson beside the Wise road, opposite Lyons Branch (location 53, elevation 1,850 B.), contains 28 inches of coal and $4\frac{1}{2}$ inches of shale 10 inches from the top of the bed. This bed is 50 feet above a bloom of the Upper Banner and eight other coals are indicated by blooms or pits along this road in a vertical interval of 230 feet above the Upper Banner bed. Most of these beds are very thin, but one lying 180 feet above the Upper Banner contains 26 inches of coal split by 13 inches of shale near the middle, and another bed, 40 feet higher, has 22 inches of coal and $1\frac{1}{2}$ inches of clay.

Nelson visited two openings near the head of Lyons Fork that are somewhat doubtfully considered to be on the Splash Dam bed and the location of which on the map is only approximate. One of these, southeast of Alka (location 54), shows 28 inches of coal and $1\frac{1}{2}$ inches of bone near the middle. The other pit includes higher benches of coal and is as follows:

Section of Splash Dam coal bed northeast of Alka.

(Location 55.)

	Ft.	in.
Coal	1	$6\frac{1}{2}$
Shale, with coal streak	3	5
Coal		$1\frac{1}{2}$
"Rash"		$\frac{1}{2}$
Coal		7
Shale	1	9
Coal	3	

Glamorgan and Lyons coal beds.—These two coals lie in a shale interval averaging about 60 feet thick and between the granular, brownish Gladeville sandstone at the base and a compact white siliceous sandstone at the top. The Glamorgan is 350 to 470 feet above the Upper Banner horizon and less than 25 feet above the Gladeville. The Lyons bed lies near the top of the shale interval and underlies only a little less territory than the Glamorgan. Both beds lie near the tops of the divides that bound the Cranesnest River drainage basin. Neither bed attains a thickness of more than 3 feet and both are commonly less than 2 feet thick.

The Glamorgan is about 2 feet thick on the northern part of the Pound-Cranesnest divide, but at the head of Bartley Branch contains only 17 inches of coal split by 12 inches of shale near the middle. The bed is thin and contains the same comparatively thick shale parting near the mouth of Long Branch and on Keel Branch.

The Lyons coal is said to be nearly 3 feet thick on the southern end of Big Ridge, and the Glamorgan is 21 inches thick at the only place measured in that district (location 56, elevation 2,575 B.). Farther north on Big Ridge neither the Glamorgan nor the Lyons has been opened in many places, though road blooms are numerous and indicate beds less than 2 feet thick. On the northern end of the ridge, half a mile north of Tarpon (location 57, elevation 1,855 H. L.), the Glamorgan is at least 2 feet thick in a road exposure and the Lyons is 50 feet higher and at least 18 inches thick.

Blair coal bed.—The Blair bed is 60 to 125 feet above the base of the Wise formation and lies a few feet above the hard white sandstone that forms the cap-rock of the Lyons coal. It underlies the higher parts of the Pound-Cranesnest divide and lies near the top of much of Big Ridge. Except where the Clintwood coal is also present, however, the Blair lies too near the surface and in areas that are too small for utilization. The coal is 2 to 3 feet thick near Clintwood and road blooms indicate that it is thinner on Big Ridge. It has not been thoroughly prospected and most of the openings that have been made are now caved.

The Blair coal has been opened on Flemming Branch (location 58, elevation 1,725 B.), where it is 33 inches thick and without noticeable partings. Three-fourths of a mile east of Clintwood (location 59, elevation 1,930 B.), the bed is 29 inches thick and has shale both above and below.

Eagle and Clintwood coal beds.—The Clintwood bed lies about 100 feet above the Blair and 185 to 230 feet above the base of the Wise formation. There is arkosic sandstone a few feet below the coal and in some places a resistant siliceous sandstone a short distance above it. The Eagle bed is 30 to 50 feet below the Clintwood. The Clintwood coal is exceptionally thick in many places, but, unfortunately, the area underlain by it in this region is small, including only the higher part of the Pound-Cranesnest divide and a small outlier on the southern part of Big Ridge. The bed splits and thins northeast of Clintwood and is $3\frac{1}{2}$ to 11 feet thick elsewhere. Very few complete measurements were made on the Eagle bed, but it is thought not to exceed 3 feet thick, and to be thinner in most places.

Near the gap between Flemming and Jerry branches (location 60, elevation 1,800 C. C. C.) there are nearly 3 feet of coal in a lower bench of the Clintwood bed, and 17 inches in another bench that lies slightly higher. In the main fork of Flemming Branch the Eagle is in two benches

of 13 inches each, with 29 inches of shale between (location 61, elevation 1,745 B.), and the Clintwood is in two benches with about 2 feet of coal in each (location 62, elevation 1,795 C. C. C.).

Several mines for local fuel supplies have been operated on the south side of Holly Creek, west and south of Clintwood. One of these, 1 mile from town (location 63, elevation 1,944 C. C. C.) shows 42 inches of coal. According to Stone, the old John Lane mine, half a mile west of town, was in 58 inches of coal, and 20 inches lower there were 35 inches more of coal and 6 inches of shale in two thin partings. The same authority states that coal at the neighboring Joe Glenn opening was 6 feet thick, including a 4-inch parting 13 inches above the floor, and that the bed was about the same thickness in openings just south of town. A small mine half a mile southeast of Clintwood (location 64, elevation 1,970 B.) is in 64 inches of clean coal in a small outlier of the Clintwood bed. A few feet below are 50 feet of soft sandstone that forms indistinct benches.

The mine that supplies most of the needs of Clintwood and vicinity is operated by Chase and Damron at the head of Long Branch, less than a mile south of the town:

Section of Clintwood coal bed at the Chase and Damron mine near Clintwood.

(Location 65, elevation 1,988 H. L.)

	Ft.	in.
Shale, black, compact.....		8
Shale, drab, removed in mining.....		8
Coal, clean	4	7
Clay		4
Coal		8-18
Coal	5	8
Partings		4

The following measurements were obtained on Keel Branch. The first is a natural exposure in the trail south from Keel triangulation station and the second a neighboring prospect reported by Stone. The poor showing at the trail exposure, as compared with other measurements on this Clintwood outlier, suggests the possibility that it is the Eagle bed or only part of the Clintwood. The third and fourth measurements were made in small mines near the head of Keel Branch.

Sections of Clintwood coal bed on Keel Branch.

(Location 66, elevation 2,025 B.)

	Ft.	in.
Shale, dark	6	
Coal	2	3
Clay, with coal streaks..	1	2
Coal	1	1
Clay		6
Coal		6
Clay, over sandstone...	9	
Coal	3	10
Partings	2	5

(Location 67, elevation 2,008 C. C. C.)

Shale.	Ft.	in.
Bone		2
Coal	5	7
Shale		½
Coal, with pyrite streak	2	11
Coal	8	6
Partings		½

(Location 68, elevation 1,962 C. C. C.)

Sandstone.	Ft.	in.
Coal	5	2
Shale, carbonaceous	2	
Coal	1	5
Coal	6	7
Partings	2	

(Location 69, elevation 1,972 C. C. C.)

	Ft.	in.
Coal	7	
Shale	1	1
Coal	2	
Coal	9	
Partings	1	1

The Clintwood coal makes an excellent showing on Honeycamp Branch, but the area underlain by it is small. The R. W. Beverly mine, on the north side of the branch (location 70, elevation 2,020 B.), is in 80 inches of clean coal. It is reported that 18 inches of coal above the bench mined are separated from it by shale, and that a coal bed 22 inches thick lies 20 feet below the mine. At the Wm. Ward bank, on the south side of the valley (location 71, elevation 2,045 C. C. C.), there are 77 inches of coal that is clean except for the common knife-edge partings of mother coal. The J. E. Beverly bank is a few rods south, on the opposite side of a narrow ridge, and shows a main bench of 78 inches and a 22-inch higher bench separated from it by 18 inches of shale.

The Clintwood is remarkably thick north of Lick Fork, but only the eastern extremities of this body of coal lie within the quadrangle. Half a mile southwest of Darwin (location 72, elevation 2,025 B.) the coal is probably correctly reported as 11 feet thick.

A measurement on the Caney Creek side of a small Clintwood outlier on Big Ridge, 5 miles south of Clintwood, is given on page 88. The section at the Elbert Powers local mine, on the Cranesnest River side, is as follows:

Section of Clintwood coal bed at Elbert Powers mine on Big Ridge.

(Location 73, elevation 2,324 H. L.)

Sandstone, shaly.	Ft.	in.
Coal	2	9
Shale		7
Coal	1	6
Clay		$\frac{1}{2}$
Coal		4
Clay		$\frac{1}{2}$
Coal	3	8
Coal	8	3
Partings		8

MC CLURE RIVER NORTHEAST OF CANEY CREEK.

Geologic outline.—The rocks exposed in the McClure River drainage basin below the mouth of Caney Creek include the Kennedy bottom-rock at the base and the lower 150 feet of the Wise formation at the top. The central part of this drainage basin lies in a structural terrace in which the only dips are minor undulations. On the southern, western, and northern borders of the basin there are northerly and northwesterly dips averaging 75 feet to the mile. The principal features of the stratigraphy of the exposed rocks are shown by the generalized columnar sections for the north and middle thirds of the Clintwood quadrangle (Pl. IV),—maximum intervals being most characteristic in the case of the north third and average intervals in the middle third. The local stratigraphy of rocks below drainage levels is shown by drill records (Pl. II), and of rocks above drainage by local sections 5 and 6.

The Kennedy, Lower Banner, Splash Dam, Glamorgan, and two other coal beds were found in this area, but the Upper Banner bed is the only one in which extensive mining could be profitably undertaken at present. (See figs. 5 and 8.) On both sides of McClure River between the mouths of Big and Road branches, the Upper Banner contains $3\frac{1}{2}$ to 6 feet of coal with only thin shale and sandstone partings, and lies sufficiently low to be easily reached from the main valleys. It is likely that mining operations on a large scale will follow the completion of the railroad along the river. Especially favorable localities are on Mill Creek and Squirrel Camp Branch.

Kennedy coal bed.—The Kennedy lies 250 to 300 feet below the Upper Banner coal horizon and is exposed only in the bottom of McClure River valley north of the mouths of Road Branch and Caney Creek. The horizon of the bed is easily identified by the coarse sandstone which is just below it,

but there appears to be little or no coal present in most places. In a railroad cut near the mouth of Spring Branch (location 74, elevation 1,340 B.), there are 16 inches of coal in what is probably the Kennedy bed, but a short distance down grade this is replaced by shale dipping about 15 degrees in what is either a slide or a local buckling. The Kennedy is 3 to 40 inches thick and greatly crushed and contorted in the tunnel at the mouth of

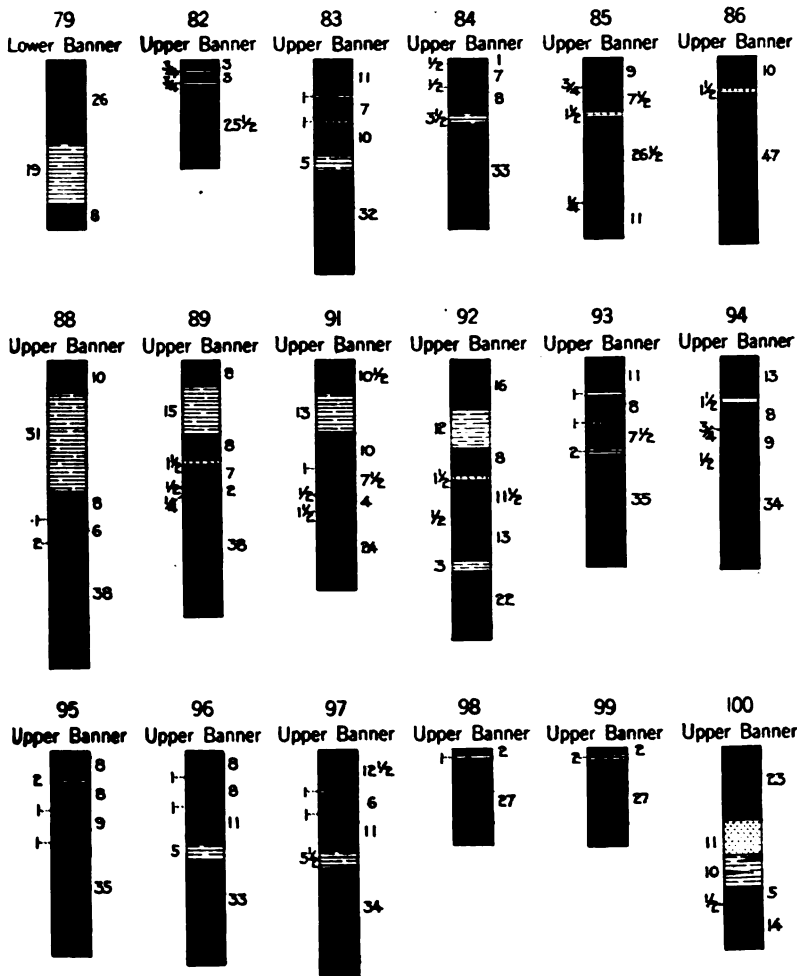


Fig. 8.—Sections of coal beds in the northern part of the McClure River drainage basin.

Caney Creek; a short distance south coal is lacking. Locally there are one or two very thin coal beds 50 feet or less above the Kennedy.

Lower Banner coal bed.—The Lower Banner lies 70 to 100 feet below the Upper Banner and outcrops low down in all of the valley of McClure River and in the lower parts of its tributaries. It has a thin sandstone bottom-rock, but can best be identified by its relations to the Upper Banner and Kennedy beds or their horizons. The coal bed is persistent, but commonly less than 2 feet thick.

The Lower Banner, 18 to 24 inches thick is exposed at the north end of the tunnel opposite the mouth of Squirrel Camp Branch (location 75, elevation 1,500 B.). Many road blooms, seeps, and a few caved pits were seen at the Lower Banner horizon west of McClure River, but no other complete measurements were obtained.

The bed is 15 and 16 inches thick, respectively, at two places in the upper part of Big Branch (locations 76 and 78). Several strip pits near the bridge at the forks of Big Branch (location 77, elevation 1,726 H. L.) show 13 to 30 inches of coal with both sandstone and shale roofs, and 2 inches more of coal 9 feet below the main bench.

No measurements were made between Big Branch and Mill Creek, and in the valley of the latter stream the value of at least the upper part of the bed is greatly impaired by shale partings.

Coal in a pit beside the ridge road near the mouth of McClure River (location 79, elevation 1,527 S.) is tentatively correlated with the Lower Banner. A short distance east the rocks dip steeply, indicating buckling, perhaps accompanied by faulting. In this pit there are 26 inches of coal underlain by 19 inches of shale under which there are 8 inches more of coal. A short distance below there is coarse-grained massive sandstone.

Upper Banner coal bed.—The Upper Banner outcrops in the valley of McClure River from its mouth to Caney Creek and also nearly to the heads of the principal tributaries. It lies 235 to 300 feet above the Kennedy horizon and 350 to 470 feet below the top of the Gladeville sandstone, the intervals thickening, in general, to the south. Between points a mile or more north of Mill Creek and a mile or less south of Big Branch and in adjacent territory west of the river, this bed includes an average thickness of 4 to 5 feet of coal and is the best mining proposition in the central or northern parts of the Clintwood quadrangle. Both north and south of this area the bed apparently breaks up into two or more relatively thin benches and it may be lacking in places. Where the bed is thick it can be easily

identified by the thin sandstone parting in its upper half and by a coarse-grained sandstone cap-rock a few inches to 20 feet above the coal.

What is probably the Upper Banner bed is less than 2 feet thick in a natural exposure in Rocky Branch (location 80, elevation 1,485 B.). The bed is 20 inches thick $1\frac{1}{2}$ miles southwest, where there are several small drifts on a point (location 81, elevation 1,615 B.). Near the tunnel opposite Hughes Branch (location 82, elevation 1,577 C. C. C.), a 32-inch bed, including two clay partings each less than 1 inch thick, is exposed in small drifts used in railroad construction work. The roof is $3\frac{1}{2}$ feet of shale under sandstone, and there is said to be another bench of coal several feet from the one mined. As shown in the two following sections, the shale parting between these two benches thins to the southwest and is only 5 inches thick in a small mine on Low Gap Branch and $3\frac{1}{2}$ inches in a drift on a point half a mile farther south:

Sections of Upper Banner coal bed near Low Gap Branch.

(Location 83, elevation 1,597 C. C. C.)			(Location 84, elevation 1,606 C. C. C.)		
Sandstone.	Ft.	in.	Sandstone.	Ft.	in.
Shale	6		Shale	5	
Coal		11	Coal	1	
Shale		1	Shale		$\frac{1}{2}$
Coal		7	Coal		7
Sandstone		1	Sandstone		$\frac{1}{2}$
Coal		10	Coal		8
Shale		5	Shale		$3\frac{1}{2}$
Coal (reported)	2	8	Coal	2	9
Coal	5		Coal	5	
Partings		7	Partings		$4\frac{1}{2}$

On the west side of McClure River the Upper Banner contains 4 to $5\frac{1}{2}$ feet of coal, with only thin partings, as far south as the mouth of Squirrel Camp Branch and a little beyond. The following was measured in a drift used in railroad construction work near the mouth of Camp Branch:

Section of Upper Banner coal bed near Camp Branch.

(Location 85, elevation 1,615 B.)				
Sandstone.			Ft.	in.
Coal			9	
Shale			$\frac{3}{4}$	
Coal			$7\frac{1}{2}$	
Sandstone			$1\frac{1}{2}$	
Coal			2	$2\frac{1}{2}$
Shale				$\frac{1}{4}$
Coal			11	
Coal			4	6
Partings				$2\frac{1}{2}$

Stone cites an opening on the west side of the river a quarter of a mile northwest of Squirrel Camp Branch, in which there are 8 inches of coal above the thin sandstone parting and 45 inches below it. A half a mile south (location 86, elevation 1,619 C. C. C.) the sandstone parting is $11\frac{1}{2}$ inches thick, the coal above it 10 inches, and that below it 47 inches; no partings more than a quarter of an inch thick were seen, and there are reported to be 15 inches more of coal $11\frac{1}{2}$ inches above the part of the bed now exposed. No measurements of the Upper Banner were obtained either west or east of McClure River between the pit last mentioned and Caney Creek, and it is probable that the bed is either thin or split into several benches in most of that area. It may be thick near the head of Big Branch, however, and a pit near the Stratton road (location 87, elevation 1,845 B.) is said to have shown nearly 3 feet of coal.

On Squirrel Camp Branch and neighboring parts of McClure River, the Upper Banner contains $3\frac{1}{2}$ to $5\frac{1}{2}$ feet of coal in a lower bench that has only thin partings, and commonly also a top bench that would probably be left up in mining. The following is exposed in a small drift mine half a mile south of the mouth of the branch:

Section of Upper Banner coal bed south of mouth of Squirrel Camp Branch.

(Location 88, elevation 1,633 C. C. C.)

	Ft.	in.
Shale.....		
Coal		10
Shale, carbonaceous at base.....	2	7
Coal		8
Sandstone		1
Coal		6
Shale		2
Coal	3	2
Coal	4	4
Partings		3

Stone states that two measurements in the upper part of the south fork of Squirrel Camp Branch were as follows:

Sections of Upper Banner coal bed on right fork of Squirrel Camp Branch.

	Ft.	in.		Ft.	in.
Coal		$8\frac{1}{2}$	Coal		10
Sandstone		$1\frac{1}{2}$	Sandstone		1
Coal		$11\frac{1}{2}$	Coal		$9\frac{1}{2}$
Shale		1	Shale		$4\frac{1}{2}$
Coal	2	$9\frac{1}{2}$	Coal		2
Coal	4	$5\frac{1}{2}$	Shale		$2\frac{1}{2}$
Partings		$2\frac{1}{2}$	Coal	2	11
			Coal	4	$8\frac{1}{2}$
			Partings		8

Following are thicknesses of the bed, as given by Stone, at two places on the north fork of the same stream:

Sections of Upper Banner coal bed on left fork of Squirrel Camp Branch.

(Location 89, elevation 1,606 C. C. C.) (Location 90, elevation 1,583 C. C. C.)

	Ft.	in.		Ft.	in.
Coal		8	Coal		9
Shale	1	3	Sandstone		1½
Coal		8	Coal		8½
Sandstone		1½	Shale		¼
Coal		7	Coal		2
Shale		½	Shale		1
Coal		2	Coal	2	8½
Shale		¼			
Coal	3	2	Coal	4	4
			Partings		2¾
Coal	4	7			
Partings		2¼			

The first of the following sections was measured at the mouth of a small mine at the forks of Squirrel Camp Branch; at the working face the coal below the sandstone parting is 42 inches thick and without shale partings. The second of the following sections is given by Stone as nearly half a mile north of the mouth of Squirrel Camp Branch.

Sections of Upper Banner coal bed near mouth of Squirrel Camp Branch.

(Location 91, elevation 1,597 C. C. C.) (Location 92, elevation 1,629 C. C. C.)

	Ft.	in.		Ft.	in.
Coal		10½	Coal	1	4
Shale	1	1	Clay	1	
Coal		10	Coal		8
Sandstone		1	Sandstone		1½
Coal		7½	Coal		11½
Shale		½	Shale		½
Coal		4	Coal	1	1
Shale		1½	Shale		3
Coal	2		Coal	1	10
Coal	3	9½	Coal	4	6½
Partings		3	Partings		5

The highest shale parting, which is sufficiently thick on Squirrel Camp Branch to render the coal above it unrecoverable, thins to the north to a few inches. The rest of the bed is about the same, so that on Mill Creek and neighboring parts of McClure Creek there are 4 to 6 feet of coal with only thin partings. The first of the following two measurements was made at a drift half a mile southwest of the mouth of Mill Creek, 90 feet above

a thin coal bed at the Lower Banner horizon; the second measurement was made at a small mine on the east side of the mouth of House Fork of Mill Creek:

Sections of Upper Banner coal bed near mouth of Mill Creek.

(Location 93, elevation 1,590 C. C. C.)			(Location 94, elevation 1,596 C. C. C.)		
Shale.	Ft.	in.		Ft.	in.
Coal	11		Sandstone		1½
Shale	1		Coal	1	1
Coal	8		Shale		1½
Sandstone	1		Coal		8
Coal	7½		Sandstone		¾
Shale	2		Coal		9
Coal	2	11	Shale		½
			Coal	2	10
Coal	5	1½			
Partings		4	Coal	5	4
			Partings		2¾

About the same thicknesses prevail farther east, as shown by the following two sections at small mines, the first on Toms Fork of Mill Creek and the second on Mill Creek near Tenso:

Sections of Upper Banner coal bed on Toms Fork and Mill Creek.

(Location 95, elevation 1,617 C. C. C.)			(Location 96, elevation 1,612 C. C. C.)		
Sandstone.	Ft.	in.	Sandstone.	Ft.	in.
Coal		8	Coal		8
Shale		2	Shale		1
Coal		8	Coal		8
Sandstone		1	Sandstone		1
Coal		9	Coal		11
Shale		1	Shale		5
Coal	2	11	Coal	2	9
Coal	5		Coal	5	
Partings		4	Partings		7

Stone describes a section near the mouth of Bowling Branch (location 97, elevation 1,612 C. C. C.) that is nearly identical with the one on Mill Creek near Tenso, the thickness of coal being 63½ inches and of partings 7½ inches. Less than a mile north of this the lowest shale parting, which is only 5 inches thick at locations 96 and 97, thickens, and still farther north is as much as 12 feet thick. As a result of this splitting, only the lower bench appears to be available for use on Road Branch, as shown by two openings (location 98, elevation 1,565 B.; and location 99, elevation 1,630 B.) at which there are 29 inches of coal and 1 or 2 inches of shale two inches from the top. The roofs are shale and the floor sandy shale

and shaly sandstone; traces of what seems to be a thin coal bed show about 10 feet above the pits, overlain by 40 feet of massive sandstone on top of which there are traces of the Splash Dam coal.

There are no openings on the Upper Banner on the east side of the McClure between Road Branch and the mouth of the river. The upper bench is only 11 inches thick where exposed near the north end of the ridge road east of the McClure, and both benches are known to be very thin near the mouth of the river. What is probably either the lower bench or both benches is exposed a mile up Camp Creek:

Section of Upper Banner coal bed on Camp Creek.

(Location 100, elevation 1,620 B.)

	Ft.	in.
Coal	1	11
Sandstone, coarse-grained	8-15	
Shale, with coal streaks	10	
Coal	5	
Shale		1½
Coal	1	2
Sandstone.		
Coal	3	6
Partings	1	10

The lower bench of the Upper Banner is 23 inches thick at the head of Camp Creek (location 101, elevation 1,670 B.), and rests upon medium-grained sandstone.

Splash Dam and higher coal beds in Norton formation.—In this area there are at least five or six Norton coal beds above the Upper Banner horizon, but only one of them—the Splash Dam—was found to be more than 13 inches thick. The Splash Dam bed is 40 to 80 feet above the Upper Banner and only a few feet above the sandstone cap-rock of the latter bed. It is nearly 3 feet thick near the mouth of the McClure, but less than 2 feet thick farther southwest. Few measurements were obtained, but the lack of prospect pits and small mines indicates that the bed is relatively unimportant.

An exposure half a mile south of Millard (location 102, elevation 1,730 B.) shows 18 inches of coal at the Splash Dam horizon, and a little more may be concealed. The same bed is reported 18 inches thick near the mouth of Road Branch (location 103, elevation 1,660 B.), and is 19 inches thick at the head of Camp Creek (on slope above location 101, elevation 1,780 B.). Coal in a pit on what is probably the Splash Dam at the mouth of McClure River (location 104, elevation 1,425 B.) appears to be about 3 feet thick. This pit is near steeply dipping beds and may not be correctly correlated.

Coal beds in Wise formation.—The Glamorgan and Lyons coal beds show as blooms in the tops of the main ridges, but underlie only small areas and are probably very thin in most places. The Blair coal has been eroded except on one or two very small outliers and the Clintwood has been removed everywhere. The Glamorgan attains a thickness of 2 feet on the northern end of Big Ridge and is probably the bed that is 25 inches thick near Hill School, northwest of Haysi (location 105, elevation 1,828 H. L.).

CANEY CREEK.

Geologic outline.—The rocks exposed in the Caney Creek drainage basin include part of the Kennedy bottom-rock at the base and the lower 300 feet of the Wise formation at the top. These are shown by the generalized columnar section for the south third of the Clintwood quadrangle (Pl. IV), by drill records C 128 and C 123 (Pl. II), and by local sections 4 and 6. Rocks not exposed are shown in drill records S 17, S 37, S 36, and S 38 (Pl. II). The Norton formation outcrops in by far the greater part of the area, as the Gladeville and Wise appear only on the tops of the highest ridges. The dips are, in general, to the northwest at 30 to 300 feet per mile.

The north half of the Caney Creek basin contains little coal that is likely to be utilized in the near future, though beds 2 feet or less thick are common and coal 3 feet thick is not unknown. Outliers of the Clintwood bed on Big Ridge contain more than 7 feet of coal and only thin partings, but are too small for any except local mines. The southern part of the basin, however, possesses rich deposits in the Upper Banner bed, which contains an average of 5 feet of excellent coal on Hurricane, Road, and Trace forks. (See figs. 4, 5, and 9.) Part of this thick coal is already being mined by the Clinchfield Coal Corporation and hauled more than a mile and a half under Sandy Ridge to the mine mouth on Fuller Branch of Big Tom Creek, whence it is shipped over the Clinch Valley division of the Norfolk and Western Railway.

Kennedy coal bed.—The Kennedy coal, which lies 250 to 330 feet below the Upper Banner horizon, is below the surface except near the mouth of Caney Creek. In the railroad tunnel near the Caney Creek bridge (location 106, elevation 1,493 H. L.) the bed is 3 to 40 inches thick and is greatly contorted and crushed, the fracture planes striking in general S. 80° E. The coal disappears a few yards north of the tunnel. The Kennedy, though locally thick, is so irregular in thickness and so crushed and fractured

that it is not a profitable mining proposition. At the tunnel there is a coarse massive sandstone under it and 100 feet of fine-grained, rather shaly sandstone above it.

Lower Banner coal bed.—The Lower Banner lies at an average distance of 100 feet below the Upper Banner horizon. It outcrops low in the valley of Caney Creek from its mouth nearly to its head and a considerable distance up its tributaries, especially those from the east. The bed averages about 2 feet thick, though locally a little more than 3 feet.

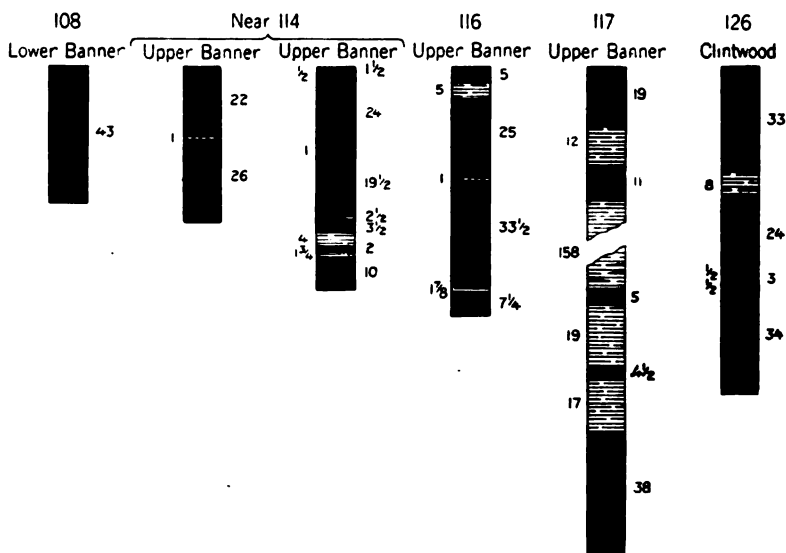


Fig. 9.—Sections of coal beds in the Caney Creek drainage basin.

No complete measurements of the Lower Banner were made on the west side of Caney Creek, though a caved pit on Mill Branch indicates a thickness of at least 2 feet, and another at the mouth of Long Branch (location 107, elevation 1,775 B.) is apparently in at least 3 feet of coal. Stone states that the bed is 21 inches thick on the upper part of Hurricane Fork, just south of the quadrangle boundary.

The bed is mined for local use on the eastern Big Branch (location 108, elevation 1,830 B.), where it is clean and 43 inches thick and is overlain by 6 feet of sandy shale and sandstone. The bed is reported to be thick in pits on the east side of the loop of Caney Creek, opposite the mouth of Long Branch. Half a mile northeast of the loop (location 109, elevation 1,790 B.) there are 34 inches of coal in an upper bench and a few inches

more below a shale parting. In the bed of the upper part of Bad Branch (location 110, elevation 1,910 B.), an exposure that appears to be the Lower Banner contains only 7 inches of coal badly split by shale partings. It is possible that this exposure is not the principal bench of coal. A prospect on Rockhouse Branch (location 111, elevation 1,820 S.) shows 26 inches of clean coal.

Upper Banner coal bed.—The Upper Banner is by far the most important coal bed in this area and outcrops 300 feet or less above Caney Creek and its tributaries from their mouths nearly to their heads. The bed contains $3\frac{1}{2}$ to 8 feet of coal, with an average of 5 feet on Hurricane, Road, and Trace forks. It is now being taken out east and west of Hurricane Fork by the Cranesnest mine of the Clinchfield Coal Corporation, the entrance to which is on the south side of Sandy Ridge and the workings of which have been driven northward a short distance into the Clintwood quadrangle. North of this district the Upper Banner splits into several parts the thickest of which contains only 2 to 3 feet of coal, and the lack of prospect pits and exposures north of Rockhouse and Mill branches indicates that there is still less coal in that district. Where the bed is thick it is characterized by an inch of sandstone in the middle or the upper half.

In a hollow near the loop of Caney Creek (location 112, elevation 1,880 B.) the Upper Banner is split into three parts occupying an interval of about 35 feet, with coarse-grained sandstone above and medium-grained sandstone below. The upper bench of coal is 18 inches thick, the middle bench 9 inches, and the lower is reported to be 30 inches. Farther south the shale between these benches thins to a few inches and the bed is the excellent mining proposition described in the last paragraph. On the right fork of Hurricane Fork (location 113, elevation 2,074 C. C. C.) small pits show the bed to be less than 2 feet thick, but either the coal is thin in a very small area here or part of the bed is not shown at the pits. At the main Caney entry of the Cranesnest mine (location 114, elevation 2,117 C. C. C.) the bed contains 6 feet of coal. The details of the bed are best shown by the following measurements in the mine, the first being 500 feet northeast of the main Caney entry and the second 1,500 feet southwest of it. The first measurement probably does not include the lower part of the bed.

Sections of Upper Banner coal bed in Cranesnest mine.

Shale.	Ft.	in.	Shale.	Ft.	in.
Coal	1	10	Coal		1½
Sandstone		1	Shale, sandy		½
Coal	2	2	Coal	2	
			Sandstone		1
Coal	4	0	Coal	1	7½
Partings		1	Shale and coal....		2½
			Coal		3½
			Shale		4
			Coal		2
			Shale		1¾
			Coal		10
			Shale.		
			Coal	5	½
			Partings		9¾

The coal available for mining thins slightly to the north, and near the junction of Hurricane and Road forks (location 115, elevation 2,060 B.) a small mine is in 42 inches of coal with the typical thin sandstone parting near the middle. Farther southeast, near the head of Trace Fork, the bed is thicker:

Section of Upper Banner coal bed near head of Trace Fork.

(Location 116, elevation 2,160 C. C. C.)

	Ft.	in.
Sandstone, bluish, medium-grained.....	6	
Coal		5
Shale		5
Coal	2	1
Sandstone		1
Coal	2	9½
Shale		1¾
Coal		7¼
Coal	5	10¾
Partings		7¾

The following measurement in pits beside the path west of Bad Ridge School apparently shows the Upper Banner in two parts, though it is barely possible that the upper part is the Splash Dam bed. The lowest and thickest bench of coal is reported to contain the typical thin sandstone parting in a few pits in the vicinity.

Section of Upper Banner coal bed half a mile west of Bad Ridge School.

(Location 117, elevation of base 1,987 S.)

	Ft.	in.
Sandstone, buff, fine-grained, shaly at base.....	5	
Coal	1	7
Shale, drab and black, carbonaceous in part.....	1	
Coal		11
Interval, including shale at top.....	8	
Shale, mostly drab, with streaks of coal in lower part; contains fossil plants.....	5	2
Coal		5
Shale, drab; contains fossil plants.....	1	7
Coal		4½
Shale, drab; contains fossil plants.....	1	5
Coal	3	2

The same beds are exposed in pits near the road on a tributary of Bad Branch, as follows:

Section of Upper Banner coal bed half a mile east of Bad Ridge School.

(Location 118, elevation of base 2,000 H. L.)

	Ft.	in.
Sandstone, buff, fine-grained, cross-bedded.....	12	
Coal, with shale streaks near top.....	1	3
Shale, very compact and sandy.....		2
Coal		6
Interval, including shale at top.....	20	
Shale, drab; contains fossil plants.....	6	
Coal		9½
Shale, carbonaceous in part.....		7
Coal	1	7
Sandstone, fine-grained, compact, massive.....	9	

On Little Rockhouse Branch (location 119, elevation 1,980 B.) the coal at the Upper Banner horizon is only 2 feet thick, and the presence of massive sandstone both above and below indicates that other benches are lacking.

Splash Dam and higher coal beds in Norton formation.—There is coal at several horizons in the Norton formation above the Upper Banner, but all the beds are less than 2 feet thick except locally. It is likely that the Splash Dam bed, which lies about 50 feet above the Upper Banner, contains as much as 2 or 3 feet of coal in places, but only blooms were found at its horizon.

The thickness of a bed that lies just above a coarse sandstone, and 280 feet and less above the Upper Banner horizon, was ascertained at two places. In one pit, in a hollow north of Pound Branch (location 120, elevation 1,980 B.), the bed contains 28 inches of coal separated by a shale parting

from 8 inches more in an upper bench. At the other pit, on Lick Branch (location 121, elevation 2,100 B.), there are only 18 inches of coal. Another bed which is 18 inches thick near Big Oak School (location 122, elevation 2,030 B.) is apparently at a lower horizon and is perhaps the Hagy.

Glamorgan and Lyons coal beds.—The characteristics of the Glamorgan and Lyons coal beds on Big Ridge have been previously mentioned in the description of coal in the Cranesnest River drainage basin. Nearly all of the exposures of these beds on the divide east of Caney Creek are on upper McClure River drainage and will be described in the section devoted to that basin.

The beds were seen at a few places on the east side of Big Ridge. A caved pit in the Glamorgan bed nearly a mile south of Bearpen Gap (location 123, elevation 2,115 B.) shows more than 18 inches of coal with 3 inches of shale near the top and a roof of 10 feet of shale. Half a mile due south the bed was reported 21 inches thick and was said to be 18 inches near the head of Pound Branch (location 124, elevation 2,215 B.). A small mine in the Lyons bed a mile northeast of Lyons (location 125, elevation 2,570 B.) was filled with water when visited, but the coal appeared to be about 3 feet thick.

Clintwood coal bed.—The Clintwood bed occurs only in small outliers on Big Ridge at the heads of Pound, Lick, and Mill branches, where it is 185 feet above the base of the Wise formation and 580 feet above the Upper Banner horizon. As shown by the following measurement at the F. T. Kenady local mine at the head of Mill Branch and by one on page 75 (location 73), it is an exceptionally thick bed in this small area. The Eagle and Blair beds, which are less than 100 feet below the Clintwood, are represented by road blooms only.

Section of Clintwood coal bed at Kenady mine on Big Ridge.

(Location 126, elevation 2,386 S.)

	Ft.	in.
Shale.		
Coal	2	9
Shale		8
Coal	2	
Shale		$\frac{1}{2}$
Coal		3
Shale		$\frac{1}{2}$
Coal	2	10
Coal	7	10
Partings		9

MC CLURE RIVER SOUTHEAST OF CANEY CREEK.

Geologic outline.—The lowest stratum exposed in the drainage basin of upper McClure River is the massive sandstone beneath the Kennedy coal bed, and the highest is a massive white sandstone the top of which is 320 feet above the base of the Wise formation. The Gladeville sandstone and the Wise formation, however, are restricted to the tops of the main ridges. The stratigraphy of strata above and below drainage is shown by generalized columnar sections (Pl. IV), by many drill records (Pls. II and III), and by local sections 7, 8, and 9. Dips are to the northwest and north at less than 100 feet per mile except locally. One normal fault with a displacement of about 30 feet has been found in mine workings in the southeast corner of the Clintwood quadrangle.

There are some important coal deposits in this area, chiefly in its southern part, near Sandy Ridge. (See figs. 4, 5, and 10.) The Kennedy coal is more than 9 feet thick in a few pockets, but is thin in many places and is everywhere crushed and very irregular in thickness. The Lower Banner is 2 to 3 feet thick in many places and contains an average of more than 3 feet of coal in the southeastern part of the area. The Lower Banner is being mined on a large scale at Dante, a short distance south of the McClure River drainage basin, where it is much the same as in part of the latter area. In the northern part of the basin the Upper Banner is split into several beds each containing less than 3 feet of coal, but these beds unite in the southeastern part of the basin, where the coal averages about 5 feet thick and contains only very thin partings of incombustible matter. A large tonnage is being derived from the Upper Banner near Dante, and the largest mine has already extended its workings north under Sandy Ridge and into the territory at the head of McClure River. A large mine at Wilder, on Dumps Creek, is also driving an entry toward the head of Roaring Fork. The Splash Dam bed is 3 to 4 feet thick in the southern part of the Open Fork drainage basin and may be fairly thick in a few other areas. Higher beds are either too thin or occupy too small an area to be of great importance. The Glamorgan and Lyons beds show 3 or 4 feet of coal locally, but commonly contain several shale partings. The Eagle bed is 30 to 51 inches thick, but underlies only about one square mile.

Kennedy coal bed.—The Kennedy coal is 300 to 420 feet below the Upper Banner horizon and outcrops low in the valley of McClure River

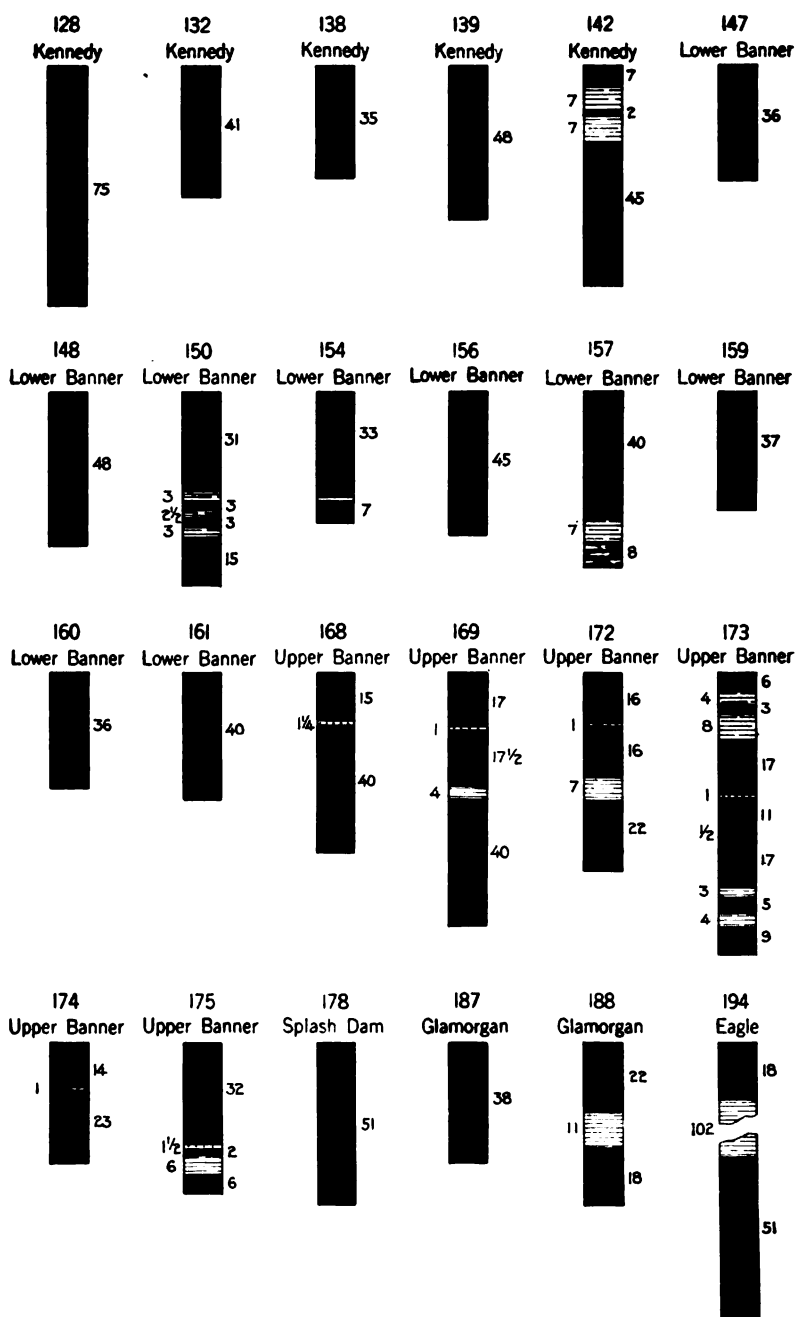


Fig. 10.—Sections of coal beds in the southern part of the McClure River drainage basin.

and the lower parts of its tributaries. The coal lies near the level of the railroad from the Sandy Ridge tunnel to Caney Creek and can be seen in many railroad cuts. The Kennedy is everywhere crushed and slickensided in greater part, and is fractured in a way that plainly shows that the beds above it were shoved to the northwest along the plane of the coal bed. As a result of this movement the thickness of the coal is remarkably irregular and the bed, though locally thick, is not likely to yield a large profit in mining. There is a coarse massive sandstone a few feet below the coal and fine-grained sandstone or sandy shale above it. There are in places several coal beds above the Kennedy and below the Lower Banner, but they are too thin or impure nearly everywhere to be of commercial importance.

The Kennedy is 3 to 40 inches thick in the tunnel at the mouth of Caney Creek, 10 to 15 inches a quarter of a mile southeast, and 12 inches half a mile farther up the railroad grade (location 127, elevation 1,501 H. L.), where it is 9 feet above the track. The Kennedy and a coal bed 30 feet higher are exposed at intervals in the cuts between Spraddle Branch and Buffalo Creek, but are too thin and irregular to be mined in even a small way.

Two small drifts on Open Fork near Rush Branch (location 128, elevation 1,600 B.) show 70 to 76 inches of coal with a sandstone roof. A small mine at the mouth of the road fork of Spring Fork (location 129, elevation 1,647 S.) is in 30 inches of coal with sandstone roof and floor. There is a large prospect pit on Middle Fork (location 130, elevation 1,630 B.) in which the Kennedy is reported $9\frac{1}{2}$ feet thick, and a small stripping a few rods south is in at least 4 feet of coal. Three feet of coal, more or less, in the pit on the opposite side of the stream are in a bed about 50 feet higher than the Kennedy. A small drift just below the mouth of Rush Branch (location 131, elevation 1,607 S.) contains only 24 to 30 inches of coal. The average thickness of the Kennedy on Open Fork drainage is much less than is indicated by these measurements.

The Kennedy is 33 feet above the grade and only 2 inches thick at the deep railroad cut at the mouth of Open Fork, and only 3 to 15 inches thick in cuts half a mile south. A little farther up grade (location 132, elevation 1,575 B.) the bed contains 41 inches of coal near track level, but is thinner not far distant. At the tunnel at the mouth of Long Branch, the following section is exposed:

Section at mouth of Long Branch of McClure River.

(Location 133, elevation of base 1,635 B.)

	Ft.	in.
Sandstone, bluish-buff, fine-grained, thick-bedded.....	45	
Shale, dark blue, slaty, buckled, with coal streaks.....	6	
Sandstone, reddish-drab, fine-grained, massive, much fractured.	19	
Coal		3-24
Shale, dark blue, slaty, buckled.....	5	
Sandstone, dark blue, argillaceous, much fractured along planes dipping 45 degrees.....	20	
Coal (Kennedy)		2-12
Sandstone, bluish, fairly coarse, massive, to railroad grade..	2	
Concealed, probably sandstone	5	
Sandstone, yellowish-buff, coarse	20	

The Kennedy is 10 to 24 inches thick in cuts near the mouth of Honey Branch (location 134, elevation 1,690 B.) and is reported 30 to 36 inches where it dips under the track a short distance north. Opposite Roaring Fork (location 135, elevation 1,700 B.), at railroad level, the bed is 24 to 37 inches thick. In cuts a short distance south the bed contains 30 inches of coal split by a foot of carbonaceous shale 10 inches from the top. Near the mouth of Bear Hollow the coal is 15 to 30 inches thick and includes irregular shale partings. Farther south (location 136, elevation 1,770 B.) the bed is 18 inches thick and has a shale parting near the middle in places. The Kennedy was utilized in railroad construction work at a mine near the end of the Sandy Ridge tunnel (location 137, elevation 1,831 S.), where it is 3 to 7 feet thick and contains shale partings of irregular thickness. The roof is 15 feet of drab, fine-grained sandstone that needs little timbering in the rooms, and 30 feet of coarse massive sandstone shows in cuts below the coal.

There are comparatively few exposures on the east side of the river, but it may be safely assumed that the Kennedy is as irregular there as along the railroad. A pit half a mile south of Nora (location 138, elevation 1,580 B.) shows coal 35 inches thick, separated from sandstone above and below by only a few inches of shale. A quarter of a mile north of Nora (location 139, elevation 1,572 S.) there is a small mine in 3 to 5 feet of coal that is clean except for irregular sandstone lenses. An analysis of coal from this mine is given elsewhere in this report. A small mine at Stratton (location 140, elevation 1,530 H. L.) is in 2 to 3 feet of coal. The bed has also been utilized about a mile northwest (location 141, elevation 1,500 B.), where it is 25 inches thick. Beside the wagon road near the mouth of Caney Creek (location 142, elevation 1,493 S.) there is a small mine in coal 54 inches thick, exclusive of two 7-inch shale partings near the top. Caved

pits a short distance north indicate that the bed is as irregular here as in the tunnel on the opposite side of the river.

Lower Banner coal bed.—The Lower Banner is 80 to 170 feet below the Upper Banner. It is separated by a few feet of shale or clay from a moderately coarse sandstone bottom-rock that is a fair marker. Its outcrop is less than 400 feet above the level of McClure River and extends a considerable distance up most of the tributaries. The coal is more regular in thickness and character than that in either the Kennedy or the Upper Banner bed; nevertheless, it is far from uniform. The bed is 2 to 3 feet thick north of Open Fork and Hatchet Branch drainage basins. It is rather thin or split by a shale parting in most of the Open Fork basin, but contains an average of more than 3 feet of coal on the upper part of the main fork. There are 3 to 4 feet of coal in most places south and southeast of Blair and Hatchet branches; although the lower part of the bed is rather impure in the northern part of this area, there is a large body of coal that will undoubtedly be mined in the near future.

The bed is poorly exposed in a stripping at water level on Spraddle Branch (location 143, elevation 1,760 B.) and is reported on unverifiable authority to be 2 to 3 feet thick.

On the tributaries and branches of Open Fork the value of the Lower Banner is impaired in many places by a shale parting near the middle. Near the head of the main fork, however, there are 3 to more than 4 feet of coal in one bench. The shale parting is 14 inches thick in a small mine on Rush Branch (location 144, elevation 1,800 B.), with 21 inches of coal above it and 13 inches below. The roof is 10 feet or more of bluish shaly sandstone. Caved pits on Spring and Middle forks do not indicate that the bed is very thick, and near the quadrangle boundary (location 145, elevation 1,965 B.) it contains only 11½ inches of coal with 2 inches of shale near the top. A partially filled strip-pit in the bed of Coon Branch (location 146, elevation 1,955 S.) and a road exposure nearly half a mile north indicate about 30 inches of coal. According to Stone this bench is separated by 2½ feet of shale from a lower bench of coal a foot thick. East of this, on Open Fork (location 147, elevation 1,945 B.), the Lower Banner is 3 feet thick and 140 feet below the Upper Banner outcrop. Nearly a mile south (location 148, elevation 1,970 B.) another small mine is in about 4 feet of coal with a sandy shale roof. The following measurements show the character of the bed farther south, the first having been made in a small mine at the mouth of Dismal Fork, and the second in a pit 40 feet below the Open Fork road.

Sections of Lower Banner coal bed near head of Open Fork.

(Location 149, elevation 1,950 B.)			(Location 150, elevation 1,955 S.)		
Sandstone.	Ft.	in.	Sandstone.	Ft.	in.
Coal	2	2	Coal	2	7
Shale		4	Shale		3
Coal		1½	Coal		3
Clay		1½	Shale		2½
Coal		3	Coal		3
Shale		1½	Shale		3
Coal		7	Coal	1	3
Coal	3	1½	Coal	4	4
Partings		7	Partings		8½

Another small mine on Open Fork (location 151, elevation 1,960 B.) contains 32 inches of clean coal at the top and 27 inches of coal with several shale partings at the bottom. Less than a mile north (location 152, elevation 1,935 B.) there are 32 inches of coal in the bed. Northeast of this, on Long Branch of McClure River (location 153, elevation 1,930 B.) the coal is 34 inches thick. In the next hollow to the south (location 154, elevation 1,900 B.) the bed is 41 inches thick, but with thin shale layers in the lower 8 inches. The floor is 6 feet of hard clay and the roof is clay shale. A short distance south of this (location 155, elevation 1,910 B.) a small mine used by railroad contractors was in 32 inches of coal with rather soft clay floor and sandstone roof over 2 inches of clay. The following sections show the character of the bed at the head of Trammel Branch:

Sections of Lower Banner coal bed at head of Trammel Branch.

(Location 156, elevation 2,136 S.)			(Location 157, elevation 2,145 B.)		
Sandstone.	Ft.	in.		Ft.	in.
Shale	1	2	Shale	2	9
Coal, clean	3	9	Coal, clean	3	4
Clay		3	Shale		7
			Coal, bony		8
Coal	3	9	Clay, soft		6
			Coal	4	
			Partings		7

A small mine near the head of McClure River (location 158, elevation 2,075 B.) is in 45 inches of coal, with 6 inches more separated from its top by 26 inches of shale. A lower seam of 6 inches is reported to be separated from the main part of the bed by 4 inches of shale. The next exposure found east of the river, in going down the McClure, was at a small mine opposite Bear Hollow (location 159), where the bed is 37 inches thick. A

small drift beside the Roaring Fork road (location 160, elevation 1,955 S.) is in 3 feet of coal that is slightly bony at base and has a sandstone roof. This thickness is below the average of the Lower Banner on Roaring Fork and the bed is also thicker in the next hollow north (location 161), where there are 40 inches of coal separated from a sandstone roof by 3 inches of shale.

The following measurements were made on Hatchet Branch, the first in a small mine on the right fork and the second in a pit beside the wagon road on the left fork:

Sections of Lower Banner coal bed on Hatchet Branch.

(Location 162, elevation 1,905 B.)

	Ft.	in.
Sandstone.		
Shale, black		10
Coal, clean	2	1
Shale		$\frac{1}{2}$
Coal, rather dirty..		7
Clay, hard.		
Coal	2	8
Parting		$\frac{1}{2}$

(Location 163, elevation 1,871 S.)

	Ft.	in.
Sandstone.		
Coal	1	11½
"Rash"	1	5
Clay		
Coal	1	11½

The "rash" in the last section is composed of interlaminated layers of coal and shale, mixed and crumpled. The bed has the same section between the forks of Hatchet Branch, in a pit just 100 feet below an opening on the Upper Banner bed.

Coal 31 inches thick was measured in a small mine in the Lower Banner on the right fork of Buffalo Creek (location 164, elevation 1,760 H. L.), the roof being a few inches of shale under sandstone and the floor 8 feet of shale over sandstone. A slightly greater thickness is reported for a caved pit in the main fork of Buffalo Creek (location 165, elevation 1,700 B.). On Crooked Creek, however, in a pit beside the wagon road (location 166, elevation 1,744 H. L.), there are only 21 inches of coal overlain by a foot of shale under sandstone.

Upper Banner coal bed.—The outcrop of the Upper Banner is well up in the hills along McClure River and extends a considerable distance up the chief tributaries. The bed is characterized by a very thin sandstone parting near the middle of the coal, and by a sandstone cap-rock commonly separated from the coal by shale. North of the basins of Open Fork and Hatchet Branch little coal was found in this area and blooms indicate that a thickening of the first shale partings above and below the thin sandstone layer has split the Upper Banner into three beds, none of which is more

than 2 or 3 feet thick. These partings are much thinner in much of the Open Fork drainage basin and on both sides of the upper part of the McClure, and there are in places five or six feet of coal in the bed. The value of this thick coal is greatly impaired in many places by partings that are sufficiently thick to make the ultimate recovery of all the coal doubtful. In the vicinity of Trammel Branch and the heads of McClure River and Roaring Fork, however, the Upper Banner is in splendid condition and is being utilized in connection with extensive operations of the Clinchfield Coal Corporation. Mines 2 and 5 have already taken out most of the Upper Banner between Trammel Branch and the head of the McClure, and coal is being mined south of Knot Hollow Branch and hauled $1\frac{1}{2}$ miles south under Sandy Ridge to the main mine mouths near Dante. The bed averages slightly more than 5 feet thick in these mines, with much of it 6 feet and some 7 feet, and sandstone and shale partings aggregate only a few inches in thickness. The main entry of mine 6 at Wilder is being driven southwest towards the head of Roaring Fork and the northeastern workings of mine 2, in coal averaging 6 feet thick.

If the following measurement, made in a small abandoned mine on Rush Branch of Open Fork, is of the Upper Banner, as appears probable, the bed is badly split by partings in this district. There is a possibility that the bed measured is the Splash Dam.

Section of Upper Banner (?) coal bed on Rush Branch.

(Location 167, elevation 1,973 C. C. C.)

	Ft.	in.
Sandstone, buff	4	
Shale, blue to black, in part carbonaceous.....	1	10
Coal	1	5
Sandstone, shaly	6	
Coal		2
Shale, very sandy at top.....		7
Coal		4
Shale		1
Coal		3
Shale	1	
Coal		5
Shale		4
Coal, bottom not seen.....	1	1
Coal in lower bed.....	2	3
Partings	2	

Near the head of Spring Fork (location 168, elevation 2,071 C. C. C.) the Upper Banner consists of 55 inches of coal with $1\frac{1}{4}$ inches of sandstone 15 inches from the top and a shale roof. The bed is thicker on Middle

Fork, as shown by the following measurements on its west side, the first being in a small mine $1\frac{1}{2}$ miles from the mouth of the fork and the second in a pit 60 feet south of the boundary of the quadrangle.

Sections of Upper Banner coal bed on Middle Fork.

(Location 169, elevation 2,052 C. C. C.)

	Ft.	in.
Sandstone	3	
Coal	1	5
Sandstone	1	1
Coal	1	$5\frac{1}{2}$
Clay	4	
Coal	3	4
Coal	6	$2\frac{1}{2}$
Partings		5

(Near mouth of Kilgore Branch.)

	Ft.	in.
Shale		
Coal		8
Shale		$3\frac{1}{2}$
Coal	1	5
Sandstone		$1\frac{1}{2}$
Coal	1	$6\frac{1}{2}$
Clay		3
Coal	1	1
Clay		7
Coal		6
Coal	5	$2\frac{1}{2}$
Partings	1	3

The first clay parting below the thin sandstone layer is thicker on Coon Branch. Stone cites a pit that is only approximately located on the map accompanying this report (location 170) and in which the thickness of the parting was reported as 35 inches, of the coal above it as 33 inches, and of the coal below it as 41 inches. There is an inch of sandstone 15 inches below the top of the upper bench of coal. A pit below the wagon road farther south (location 171, elevation 2,053 S.) shows 35 inches of coal in what is probably the upper bench of the Upper Banner, and there is reported to be 41 inches more below, separated from it by 3 feet of shale.

The character of the bed near the head of the main branch of Open Fork is shown by the following measurements, the first in a small mine and the second in a prospect pit:

Sections of Upper Banner coal bed near head of Open Fork.

(Location 172, elevation 2,140 B.)

	Ft.	in.
Sandstone		
Coal	1	4
Sandstone		1
Coal	1	4
Shale		7
Coal	1	10
Coal	4	6
Partings		8

(Location 173, elevation 2,100 B.)

	Ft.	in.
Sandstone		
Coal		6
Shale		4
Coal		3
Clay		8
Coal	1	5
Sandstone		1
Coal		11
Shale		$\frac{1}{2}$
Coal	1	5
Clay		3
Coal		5
Clay		4
Coal		9
Coal	5	8
Partings	1	$8\frac{1}{2}$

The thickness of the Upper Banner in the mines near the head of McClure River has been mentioned and details of the bed are shown in the following sections. The first measurement was made a few yards south of the Clintwood quadrangle, in a small mine near the wagon road up Trammel Branch; the second was obtained between Knot Hollow Branch and McClure River, in the workings of mine 2 of the Clinchfield Coal Corporation.

Sections of Upper Banner coal bed near head of McClure River.

	Ft.	in.		Ft.	in.
Shale	6		Sandstone	1	10
Coal	1	11½	Coal	1	1½
Sandstone		1	Sandstone	1	2½
Coal		7½	Sandstone		½
Clay		½	Coal	2	5
Coal	2	3			
			Coal	5	5
Coal	4	10	Partings		2
Partings		1½			

The bed is thinner and more irregular on Roaring Fork, as indicated by the following sections:

Sections of Upper Banner coal bed on Roaring Fork.

(Location 174, elevation 2,110 B.)

	Ft.	in.
Coal	1	2
Sandstone		1
Coal	1	11
Coal	3	1
Parting		1

(Location 175, elevation 2,125 B.)

	Ft.	in.
Coal	2	8
Sandstone		1½
Coal		2
Shale		6
Coal		6
Coal	3	4
Partings		8

A pit on Hatchet Branch (location 176, elevation 2,000 B.) shows only 27 inches in the Upper Banner bed, including 3 inches of clay 2 inches below the top of the coal. The roof is 8 feet of drab shale and the floor 18 inches or more of yellow clay.

Splash Dam and higher coal beds in Norton formation.—There are Norton coal beds at 5 or 6 horizons above the Upper Banner, but most of them are everywhere very thin and were laid down in rather small areas. The Splash Dam bed lies 30 to 90 feet above the Upper Banner and is separated from it chiefly by sandstone. The bed is thin in most places, but is known to contain 3 to 4 feet of coal in the southern part of the Open Fork drainage basin and is probably workable in a few other areas



Views showing forested conditions; (A) Railway cut $2\frac{1}{2}$ miles southwest of the mouth of McClure River; (B) Ridges east of the head of Hatchet Branch of McClure River.

where it has not been thoroughly prospected. The Hagy bed, which is about 185 feet above the Upper Banner, was found to contain 24 to 30 inches of workable coal at two places.

There is a caved prospect pit in the Splash Dam bed just above the wagon road up Coon Branch of Open Fork (location 177, elevation 2,097 S.), 41 feet above the top of the Upper Banner. A road bloom near this indicates that the bed is about 5 feet thick, including, perhaps, one or two thin shale partings. A pit near the head of the main branch of Open Fork (location 178, elevation 2,190 B.) is 50 feet above an opening in the Upper Banner and is in coal 51 inches thick. Farther down the fork (location 179, elevation 2,110 B.) the bed is about 4 feet thick, including two shale partings.

The Hagy bed, which lies under a conglomeratic sandstone in this area, contains 34 inches of coal on Low Gap Branch of Spring Fork (location 180, elevation 2,285 B.), but is split by 13 inches of shale 10 inches above the base. A partial exposure in the bed of a tributary of Buffalo Creek (location 181, elevation 2,055 B.) shows 30 inches of coal at the top and 12 inches at the bottom, separated by an interval of 32 inches that may be in part coal.

Glamorgan and Lyons coal beds.—The Glamorgan and Lyons beds outcrop only close to the tops of the main ridges and, consequently, underlie only a small area. The Glamorgan is 10 to 25 feet above the top of the thick Gladeville sandstone and in places is split into two beds 10 or 20 feet apart. The Lyons is about 50 feet higher and is not far below the base of a conspicuous white siliceous sandstone. The Lyons is poorly exposed and is commonly thin. The Glamorgan has been utilized by people living on the ridges and appears in many natural exposures. It contains 2 to more than 3 feet of coal in many places, but several shale partings greatly impair its value. It is thickest in the southern part of the area.

The Glamorgan was reported to be 2 feet thick in post-holes near Big Oak School, north of Spraddle Branch, and 30 to 36 inches thick in pits near Smith School, south of the same stream. Shale partings were probably included in the thicknesses given. Many blooms were seen, but no reliable measurements were obtained in this district.

Two small mines on the ridge west of Spring Fork, the first near Leck and the second at the head of Low Gap Branch, show many irregular partings in the Glamorgan:

Sections of Glamorgan coal bed near Leck.

(Location 182, elevation 2,615 S.)

	Ft.	in.
Shale	2	
Coal		10
Clay	2	6
Coal	1	9
Clay		10
Coal		8
Coal	3	3
Partings	4	

(Location 184, elevation 2,585 B.)

	Ft.	in.
Shale	15	
Coal		6½
Shale		½
Coal		5½
Shale		2½
Coal		8½
Rash		1
Coal		8
Clay		5¼
Coal		7½
Coal	3	
Partings		9¼

The Glamorgan contains 35 inches of coal and 4 inches of clay 11 inches below the top at a spring on the ridge between House and Low Gap branches (location 183, elevation 2,590 B.). The upper part is rather dirty and has the argillaceous shale roof characteristic of the bed; friable reddish sandstone outcrops a few feet below the coal. A coal bed 30 feet above the one previously mentioned is said to be 2 feet thick on the ridge south of Low Gap Branch, and one of these two beds is reported on apparently good authority to have 4 feet of clean coal near the head of Spring Fork (location 185, elevation 2,580 B.). At Rasnake School, at the head of Coon Branch, shale partings that are very irregular in thickness may be seen in a small mine:

Section of Glamorgan coal bed at head of Coon Branch.

(Location 186, elevation 2,550 B.)

	Ft.	in.
Shale		
Coal	1	
Shale		8-12
Coal	1	3
Shale		18-24
Coal		6
Shale	12	
Coal		12-14
Coal	2	9
Partings	2	7

Clean coal 38 inches thick was seen in a small mine near Smith School, by the ridge road west of McClure River (location 187, elevation 2,673 H. L.). This bed may be a little higher stratigraphically than the one mined at Rasnake School.

There is sandstone a short distance above, as well as below, the Glamorgan on Flat Spur and neighboring parts of Sandy Ridge. A small mine near the southern part of Flat Spur (location 188, elevation 2,738 H. L.) shows 40 inches of coal in the bed, but with a parting of 11 inches of shale near the middle. Road blooms in this district show several thin coal beds in an interval of 100 feet above the Glamorgan, but the Lyons bed is nowhere fully exposed. The Lyons is 30 inches thick in the Sandy Ridge road east of Roaring Fork (location 189, elevation 2,840 B.), but is only 13 inches thick half a mile north, near the school.

No complete exposures of the Glamorgan or Lyons beds were seen on the ridges northwest of Flat Spur, but the former bed is reported to be 2 or 3 feet thick in a shallow well near the triangulation station at the head of Hatchet Branch, and 12 to 18 inches thick on the divide between McClure River and Crooked Branch (location 190, elevation 2,320 B.).

Blair and Eagle coal beds.—The Blair coal lies a few feet above a ledge-making sandstone and about 120 feet above the base of the Wise formation. The Eagle is about 60 feet higher, beneath a more or less massive sandstone. These beds outcrop only on Flat Spur and a few of the highest parts of other ridges. The Clintwood coal was not found, though its horizon outcrops in a small area on the end of Flat Spur.

The Blair bed contains 20 inches of coal and 3 inches of shale on the northern part of Flat Spur (location 191). On the southern part of the spur there are 22 inches of coal split in the middle by a 9-inch shale parting.

The Eagle bed was measured at the head of Hollow Branch (location 192, elevation 2,830 B.), where there are at least 30 inches of coal in a lower bench and 6 inches more 3 feet higher. The roof is 22 inches of shale under a thick sandstone. The same measurements were obtained in an opening 500 feet to the north. There are at least 35 inches of coal in the Eagle bed on the east side of Flat Spur (location 193, elevation 2,870 B.). A small outlier of the same bed north of Roaring Fork (location 194, elevation 2,890 B.) contains one bench of coal about 51 inches thick and another 18 inches thick and 8½ feet above the first.

LICK CREEK.

Geologic outline.—Rocks exposed in the drainage basin of Lick Creek of Russell Fork extend from about 180 feet below the Kennedy coal horizon to 250 feet above the base of the Wise formation. The Gladeville sand-

stone, however, appears only on the tops of high ridges and the Wise only on high knobs on the western and southern borders of the basin. Stratigraphic features are shown graphically in the generalized columnar sections for the south and middle thirds of the Clintwood quadrangle (Pl. IV), the intervals being nearly the maximum shown in both sections. The graphic records of borings within the area (Pl. II) show the succession of rocks below the surface, and those of holes bored on the ridges farther south and southeast (Pls. II and III) are applicable in a general way to the outcropping rocks of the area. Local sections 7 and 10 also show stratigraphic details. Except near the mouth of Lick Creek, where the proximity of a shearing zone has caused minor complications, the structure is simple and dips are, in general, northwest and north at about 50 feet per mile.

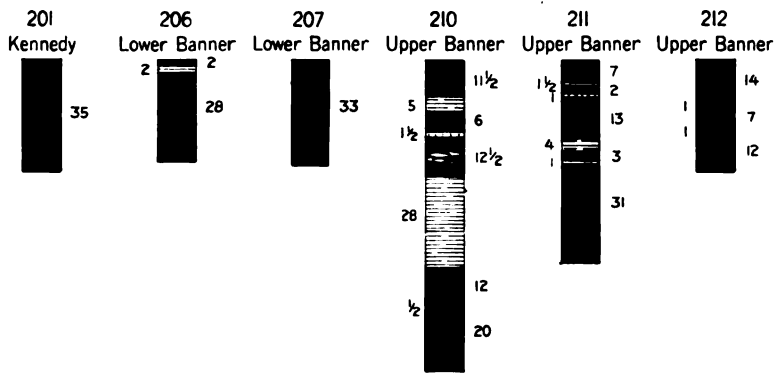


Fig. 11.—Sections of coal beds in the Lick Creek drainage basin.

The Lick Creek basin contains a number of coal beds, but the only ones of special commercial importance are the Kennedy, Lower Banner, and Upper Banner. (See figs. 4, 5, and 11.) The Kennedy is as much as 5 feet thick in places, but is commonly much thinner. The Lower Banner is 2 to 31½ feet thick in the southern part of the basin and averages less elsewhere. The Upper Banner is the most important bed, especially on Beech Branch and neighboring parts of Lick Creek. The bed contains 4 to 6 feet of coal, but is split by shale partings into two or more parts except on Beech Branch and, possibly, under the ridges near Flint Gap School. The parts of the bed are so far apart in most places that they must be mined separately, and in places neither part is as much as 2 feet thick.

Aily coal bed.—The lowest exposed coal bed in the area is the Aily, which is about 90 feet below the Kennedy coal horizon and outcrops near the level

of Lick Creek from near its mouth nearly to Josh Branch. As exposed in a pit at Aily (location 195, elevation 1,410 B.) it is 18 inches thick and rests upon sandstone. The roof in this district is a few feet of sandy shale containing fossil plants and overlain by thick beds of sandstone. The Aily is 19 inches thick at the mouth of Hurricane Branch (location 196, elevation 1,320 B.), where it has the same type of roof and floor.

Kennedy coal bed.—The Kennedy is 250 to 320 feet below the Upper Banner and outcrops low down in the valley of Lick Creek. In this area, as elsewhere west of Russell Fork and Indian Creek, the Kennedy is very irregular in thickness, ranging from a few inches to 5 feet or more. The horizon of the bed is easily determined, as it lies only a few feet above a conspicuous coarse and massive sandstone and underlies shale and fine-grained sandstone of considerable thickness.

The Kennedy is reported a little more than 2 feet thick near the mouth of Lick Creek (location 197, elevation 1,405 B.). The bed is thicker farther south, for it is reported to be 4 feet thick at the mouth of the southern Linn Branch (location 198, elevation 1,575 B.) and 5 feet at the mouth of Cabin Creek (location 199, elevation 1,580 B.). The accuracy of these reports could not be verified. The following section was measured on Left Fork, half a mile from its mouth:

Section of Kennedy coal bed on Left Fork of Lick Creek.

(Location 200, elevation 1,480 B.)

	Ft.	in.
Coal		1
Shale		½
Coal	1	11
Shale		1
Coal		6
Coal	2	6
Partings		1½

The coal is 35 inches thick on Upper Hurricane Branch (location 201, elevation 1,485 H. L.) and has a massive sandstone floor and fossiliferous shale in the roof.

Lower Banner coal bed.—The Lower Banner coal is 50 to 110 feet below the Upper Banner and outcrops in the valleys of Lick Creek and its tributaries from their mouths nearly to their heads. The bed has not been thoroughly prospected, but probably averages about 30 inches thick, being, in general, 2 feet or less in the northern part of the drainage basin and 2 to 3½ feet in the southern part. The roof is commonly a very sandy shale and there is a sandstone bottom-rock a few feet below the coal.

The Lower Banner is at least 18 inches thick at Aily (location 202, elevation 1,690 B.), where all of the bed may not have been exposed. At the mouth of Wolfpen Branch (location 203, elevation 1,853 S.) the roof is a very sandy shale and the coal is 28 inches thick and somewhat fractured and crushed. A stripping in 16 inches of coal near the head of Wolfpen Branch (location 204, elevation 1,930 B.) has not reached the bottom of the bed. The bed is reported to be 42 inches thick near the head of Long Branch (location 205, elevation 1,935 B.); but this may not be accurate. Less than half a mile north, near Debusk (location 206, elevation 1,915 B.), the bed is 32 inches thick, including 2 inches of shale 2 inches from the top. The Lower Banner consists of 33 inches of clean coal in a pit on Low Gap Branch (location 207, elevation 1,950 B.).

The only measurement of the bed obtained east of the lower part of Lick Creek was on Hurricane Branch (location 208, elevation 1,680 B.), where it is at least 19 inches thick and contains two very thin shale partings. It is possible that all of the bed was not seen at this place.

Upper Banner coal bed.—The outcrop of the Upper Banner is 300 to 500 feet above stream level along most of Lick Creek and extends up its tributaries nearly to their heads. The characteristics of the bed are much the same as on lower McClure River. On the upper part of Beech Branch the coal is 4 to 6 feet thick and contains only thin partings, being evidently part of the body of thick coal on Mill Creek and Squirrel Camp Branch of the McClure. At the mouth of Beech Branch, however, the partings thicken and the coal splits into two or three separate beds to both the north and south on Lick Creek. The distance between the two principal benches along the creek near Beech and Turkey branches and Aily is only a few feet and the lower bench is as much as 3 feet thick. About a mile south of Aily the two benches are 45 feet apart. Comparatively little is known about the Upper Banner in the southern and northeastern parts of the Lick Creek drainage basin, but there are indications that the bed is split into at least two distinct and rather thin benches in all of that territory except near Flint Gap School. The 1-inch sandstone parting that is characteristic of the Upper Banner is near the middle of the upper bench where the bed is split.

Coal in a pit on a spur east of the northern Linn Branch (location 209, elevation 1,710 B.) is said to be only 18 inches thick and is evidently in the lower split of the Upper Banner, as massive sandstone shows just below it. As shown by the following two measurements, the parting between the two benches is only 28 inches thick on the spur west of Turkey Branch,

and is 4 inches thick near the head of Beech Branch. The upper part of the Beech Branch section was measured by Stone, and a 7-inch coal seam was found about 8 feet above the principal bed.

Sections of Upper Banner coal bed on Turkey and Beech branches.

(Location 210, elevation 1,763 C. C. C.)

	Ft.	in.
Shale	3	
Coal		11½
Shale, carbonaceous...	5	
Coal	6	
Sandstone		1½
Coal, in part bony..	1	½
Shale	2	4
Coal	1	
Rash		½
Coal	1	8
Coal	5	2
Partings	2	11

(Location 211, elevation 1,724 C. C. C.)

	Ft.	in.
Sandstone.		
Coal		7
Shale		1½
Coal		2
Sandstone		1
Coal	1	1
Clay		4
Coal		3
Clay		1
Coal (reported) .	2	7
Coal	4	8
Partings		7½

An opening on Laurel Branch, west of Flint Gap School (location 212, elevation 1,960 B.) shows 33 inches of coal, with an inch of shale 14 inches from the top and an inch of sandstone a foot from the bottom. The lower part of the Upper Banner, seen on Turkey and Beech branches, was not found here, though the parting between it and the upper part is only a foot thick a mile northeast, on Breeden Branch of Fryingpan Creek.

The Upper Banner was reported to be 43 inches thick near the mouth of Big Branch of Left Fork (location 213, elevation 1,820 B.), but the thickness of shale partings is not known.

Higher coal beds.—Coal was found at a number of places at horizons higher than that of the Upper Banner, but in nearly all cases it was too thin to be of even local importance. The Splash Dam bed, which is about 50 feet above the Upper Banner, is probably 2 or 3 feet thick in small areas, and one or more higher coal beds in the Norton formation may be 2 feet thick in places. The Glamorgan and Lyons beds, near the base of the Wise formation, are poorly exposed and occupy only very small areas on some of the ridge tops. The Glamorgan is reported to be 3 feet thick at a stripping on Wampler Ridge, at the head of Spring Branch (location 214, elevation 2,720 H. L.), and has a roof of fossiliferous clay shale that is very soft at base. In the road near this, the Lyons bed is 23 inches thick. The Blair and Eagle beds underlie only a few very small areas on the highest parts of the ridges, but have not been prospected.

FRYINGPAN CREEK.

Geologic outline.—All of the Norton formation except the lower 150 feet is exposed in the Fryingpan Creek drainage basin, the Gladeville sandstone caps some of the highest ridges, and 250 feet of the Wise formation still remain on part of Wampler Ridge. The stratigraphic character of the rocks both above and below drainage is shown graphically by the generalized columnar sections for the middle and south thirds of the Bucu quadrangle (Pl. IV) and by the logs of numerous borings in the southwestern part of the Bucu quadrangle (Pl. III). Exposed rocks are also shown in local sections 10, 11, and 29. There is a general thinning of strata to the north, though the sandstone cap-rock of the Upper Banner coal bed thickens slightly in that direction.

The direction of the dip is, in general, northwest at 50 to 250 feet per mile, but in part of the basin the dip is nearly due west and in another part due north. North of Bucu, moreover, there is a small dome, so that some dips in that district are to the south and east. In a small area near Priest Fork and neighboring parts of Fryingpan Creek, there are in places steep and irregular dips caused by buckling and shearing. It is almost certain that all the exposed rocks in this area are of Norton age, but no attempt has been made to define the position of coal outcrops and structure contours on the map.

Very little coal was found in the northern part of the area and it is not likely that many deposits more than 2 or 3 feet thick exist. The Kennedy is locally thick, but is thin in most places. In the west-central and southern parts of the area, however, there is thick coal in parts of the Tiller and Jawbone, Garden Hole, Lower Banner, and Upper Banner beds, as well as coal about 4 feet thick in an outlier of the Eagle bed that is too small to be of commercial significance. (See figs. 3, 4, 5, and 12.) The Tiller and Jawbone coals, which are so close together that they are practically one bed, contain 4 to 6 feet of slightly impure coal where they are exposed along Fryingpan Creek near Bucu. The united beds probably also form a thick deposit in the region east and southeast of Bucu, where they are below drainage levels. The Garden Hole bed is less than 30 inches thick in most places, but is as much as $4\frac{1}{2}$ feet thick a short distance south and southeast of Bucu. The Lower Banner is a clean bed 2 to 4 feet thick between Lick Branch and Sandy Ridge. The Upper Banner includes 3 to 7 feet of recoverable coal between Breeden and Hardin branches and in the district east of Fryingpan Creek and south of Lick Branch. Elsewhere the

thickening of a shale parting is thought to separate the bed into two parts, though it is possible that more extensive prospecting may increase the known acreage of thick coal.

Tiller and Jawbone coal beds.—The Tiller and Jawbone beds lie 750 to 825 feet below the Upper Banner horizon, and are only a few inches apart where they are exposed along Fryingpan Creek between Hardin and Lick branches. There is a thin sandstone stratum a few feet above the coal, separated from it by shale, and a siliceous conglomeratic sandstone a few feet below it. The coal is 4 to 6 feet thick where openings were found, but is rather impure and commonly contains a thick parting of shale mixed with coal ("rash").

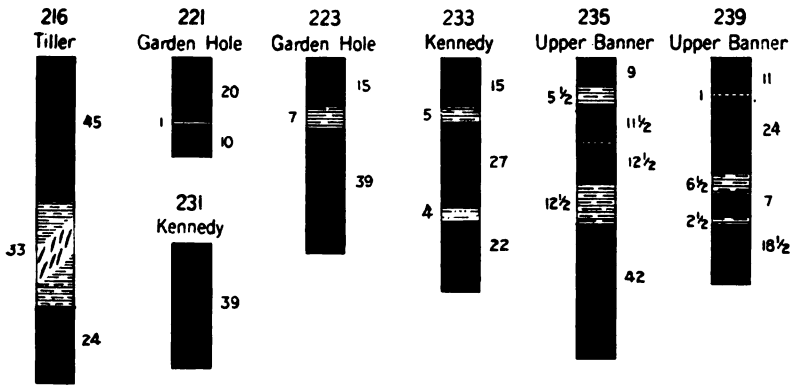


Fig. 12.—Sections of coal beds in the Fryingpan Creek drainage basin.

The bed has been utilized at several openings at Bucu. In a small mine on the west side of the creek (location 215, elevation 1,522 S.) there are 42 inches of coal that is somewhat bony in the middle, overlain by 10 feet of shale, and underlain by at least 24 inches of coal and clay mixed and interfoliated and with slickensided surfaces. That all of the bed is not exposed is indicated by the following section, measured in another small mine a short distance south:

Section of Tiller and Jawbone coal beds at Bucu.

(Location 216, elevation 1,496 S.)

	Ft.	in.
Shale, yellowish-gray, argillaceous.....	1	
Coal	3	9
Shale, in part mixed with coal, irregularly foliated along curved planes	2	9
Coal, not well exposed.....	2	
Coal	5	9
Parting	2	9

The upper bench of coal, 45 inches thick, is mined on a small scale in front of the store at Bucu (location 217, elevation 1,525 H. L.). Near the wagon road, a little more than half a mile north of Bucu (location 218, elevation 1,565 B.), the coal is 40 inches thick and all except the upper 10 inches is foliated and slickensided. The roof is 4 feet of thin-bedded sandstone. The coal is reported to be about the same thickness half a mile down the creek and a thick coal bloom shows in the road.

A bed that lies 25 to 60 feet above the Tiller and Jawbone commonly contains less than 30 inches of coal in this area and is less than a foot thick in many places. Half a mile west of the mouth of Priest Fork (location 219, elevation 1,390 B.) this bed is 21 inches thick, but is split into two parts by shale a short distance down the creek. An exposure at stream level at the mouth of Hardin Branch (location 220, elevation 1,425 B.) contains 17 inches of coal under 50 feet of thin-bedded sandstone and sandy shale. At Bucu the coal is about 20 inches thick and 25 feet above the Tiller and Jawbone beds.

Garden Hole and associated coal beds.—The Garden Hole bed is 110 to 200 feet above the Jawbone horizon and is thin in most places. It contains 24 to 30 inches of coal in places in the northern part of the area and 2 to 4½ feet along Lick Branch and neighboring parts of Fryingpan Creek; elsewhere it is thin and commercially unimportant. There is also coal at four or five horizons between the Garden Hole and Kennedy beds, but no exposure of more than 2 feet of coal was seen and it is probable that these beds are everywhere thin. There are no reliable stratigraphic markers in this part of the section, so that the identification of the Garden Hole is difficult and may be in error in places.

The Garden Hole bed is 31 inches thick, including an inch of shale in its lower half, at a small mine near Bucu (location 221, elevation 1,640 B.), and has a thin-bedded sandstone roof. On the opposite or south side of Cabin Branch the bed is 15 feet lower and there is a foot of coal 6 feet above the thicker bench. An exposure of 27 inches of coal with a dark blue shale roof near stream level at Lick Branch School (location 222, elevation 1,650 B.) may be the Garden Hole, but is probably a bed a short distance above it. A small mine above the road near the mouth of Lick Branch (location 223, elevation 1,613 S.) is certainly in the Garden Hole bed. The roof is sandstone and the bed contains 54 inches of coal and a 7-inch shale parting 15 inches from the top. The Garden Hole appears to be in two benches about 30 feet apart farther south, and the upper bench was reported to be about 3 feet thick in a stream cut at the mouth of Breeden Branch (location 224, elevation 1,403 H. L.).

Coal 16 inches thick is exposed at the level of a small tributary of Priest Fork (location 225, elevation 1,340 B.). The irregular laminæ of the coal have slickensided surfaces caused by movement along the bed, and the irregular dips of strata in the vicinity make it uncertain whether this is the Garden Hole or one of the higher beds. The same features characterize an exposure beside the path up Priest Fork (location 226, elevation 1,400 B.), where the coal is 22 inches thick. Farther up Priest Fork (location 227, elevation 1,455 B.) an opening in what is probably the upper bench of the Garden Hole bed shows 22 inches of coal split in the middle by 5 inches of shale and dipping 2° west of south. Both benches are exposed opposite a house half a mile southeast, as follows:

Section of Garden Hole coal bed on Priest Fork.

(Location 228, elevation 1,510 B.)

	Ft.	in.
Shale, blue to dark drab, with coal streak near base.....	5	6
Coal		9
Clay and coal, mixed		2½
Coal	1	1½
Concealed	13	
Sandstone, medium-grained	5	
Coal bloom		

One of the beds between the Garden Hole and Kennedy horizons is 19 inches thick where exposed in the bottom of a small hollow near Abners Gap (location 229, elevation 1,560 B.). Coal 16 inches thick may be seen by the road near the forks of Priest Fork, but the irregular dips of strata in the vicinity make its correlation doubtful.

Kennedy coal bed.—The Kennedy lies 280 to 380 feet below the Upper Banner horizon, the interval decreasing to the north. It has not been prospected much in this area, so that its thickness is not well known. Its character in neighboring areas suggests that it is irregular in thickness, is locally thick, and is thin in most places. It contains 64 inches of coal at one place, as described below.

The Kennedy appears to be about 3 feet thick in a caved pit on Rock Lick Branch (location 230, elevation 1,540 B.). There are 39 inches of clean coal with sandstone roof and floor in a small mine near the mouth of Breeden Branch (location 231, elevation 1,655 B.). Near the head of Fryingpan Creek (location 232, elevation 1,950 B.) the bed is only 15 inches thick, but it is much thicker in at least one place in the northern part of the area, as shown in the following section:

Section of Kennedy coal bed 1 mile southwest of the mouth of Priest Fork.

(Location 233, elevation 1,570 B.)

	Ft.	in.
Sandstone.		
Coal	1	3
Shale		5
Coal	2	3
Shale and fine-grained sandstone.....		4
Coal	1	10
Sandstone.		
Coal	5	4
Partings		9

Lower Banner coal bed.—The Lower Banner lies about 100 feet below the Upper Banner. No complete measurements were obtained, but the bed is reported to be nearly free from shale partings and to contain 2 to 4 feet of coal in the southern part of the area, near Sandy Ridge and as far north as Lick Branch. The thickness of 34 inches of clean coal measured above the wagon road at the head of Fryingspan Creek (location 234, elevation 2,220 B.) is below rather than above the average for this district. North of Lick Branch the bed is probably thinner in most places and may be absent in part of the district between lower Fryingspan Creek and Russell Fork.

Upper Banner coal bed.—The Upper Banner lies only a few hundred feet below the tops of the higher ridges in this area, and is a thick and important bed in two districts, where it includes 3 to 7 feet of coal, the characteristic very thin sandstone parting, and two or more shale partings commonly aggregating less than 1 foot in thickness. One of these districts, as now known, lies between the heads of Breeden and Hardin branches and will probably be shown by additional prospecting to extend somewhat farther north and south. The other district is in the area east of the upper part of Fryingspan Creek and south of Lick Branch. Outside these districts the principal shale parting below the thin sandstone layer thickens and separates the bed into two parts, each containing less than 3 feet of coal. Nothing is known about the condition of the bed east of Fryingspan Creek and north of Lick Branch, but it is probable that it is split into two parts in nearly all of the area and that both parts thin to the north.

The most southern measurement was obtained in a pit below the wagon road on the upper part of Breeden Branch, and is as follows:

Section of Upper Banner coal bed on Breeden Branch.

(Location 235, elevation 1,925 B.)

	Ft.	in.
Shale, sandy	2	
Coal		9
Clay, carbonaceous		5½
Coal		11½
Sandstone, carbonaceous		1
Coal	1	½
Shale	1	½
Coal	3	6
Coal	6	3
Partings	1	7

The partings are thinner at the head of Hardin Branch, where the total bed was reported to be 6 or 7 feet thick at two caved prospects (locations 236 and 237, elevation 1,990 B.) lying under a massive sandstone 35 to 50 feet thick. The following two measurements in the same locality are cited by Stone:

Sections of Upper Banner coal bed on Hardin Branch.

	Ft.	in.		Ft.	in.
Shale, under sandstone	6		Shale	4	
Coal	11		Coal	9	
Clay		½	Coal, laminated.		½
Coal	10		Coal	9	
Sandstone		1¼	Sandstone		1½
Coal	1	5	Coal	1	
Clay		6	Coal, laminated.		4
Coal (seen)	2	6	Shale		10
			Coal	1	5
Coal	5	8	Shale		1
Partings		7¾	Coal	1	6
			Coal	5	9½
			Partings	1	½

The following two sections show the character of the bed in the district south of Lick Branch. The first section is cited in Stone's report and the location is only approximate; the second is from a pit on a spur southeast of the mouth of Lick Branch. Other measurements are given in the description of the Upper Banner in the Indian Creek drainage basin.

Sections of Upper Banner coal bed south of Lick Branch.

(Location 238, elevation 2,340 ?.)		(Location 239, elevation 2,310 B.)	
	Ft. in.		Ft. in.
Shale, under sandstone..	8	Sandstone.	
Coal	8	Coal	11
Sandstone	1	Sandstone	1
Coal	1	Coal	2
Clay and coal.....	1	Clay	6½
Coal	1	Coal	7
Shale	3	Shale	2½
Coal	1	Coal	1 6½
		Coal	5 ½
Coal	4 11	Partings	10
Partings	1 4		

Splash Dam and higher coal beds.—There is coal at a number of horizons above the Upper Banner, but only one complete measurement of any of them was obtained in this area. It is probable that the Norton beds above the Upper Banner are less than 3 feet thick everywhere, and less than 2 feet nearly everywhere. The Glamorgan, Lyons, and Eagle coal beds, in the Wise formation, occupy small areas on Wampler Ridge and measurements of them have been given in the description of coal in the Lick Creek and upper McClure River drainage basins.

The Splash Dam bed was measured at one place, at the head of Hardin Branch (location 240, elevation 2,200 B.), where it is 23 inches thick and has a thin streak of sandstone near the middle. The sandstone streak is much like that in the upper part of the Upper Banner bed, but the stratigraphic relations and topographic position of this exposure indicate that it is the Splash Dam.

INDIAN CREEK.

Geologic outline.—The upper 150 feet of the Lee formation, all of the Norton formation and Gladeville sandstone, and the lower 250 feet of the Wise formation are exposed in the Indian Creek drainage basin. The upper part of the Lee appears only in the bottoms of parts of the principal valleys, and other Lee rocks are exposed in the small faulted area at the head of Lambert Fork. The Gladeville and Wise were found only in small outliers on the high ridges on the southwest and in a small area near the head of Lambert Fork. The stratigraphic succession is indicated by generalized sections on Plate IV, by local sections 11, 12, and 13, and by drill records (Pl. III).

The dominant structural feature of the central part of the area is the Sourwood Mountain anticline, an elongated dome with rather steep sides

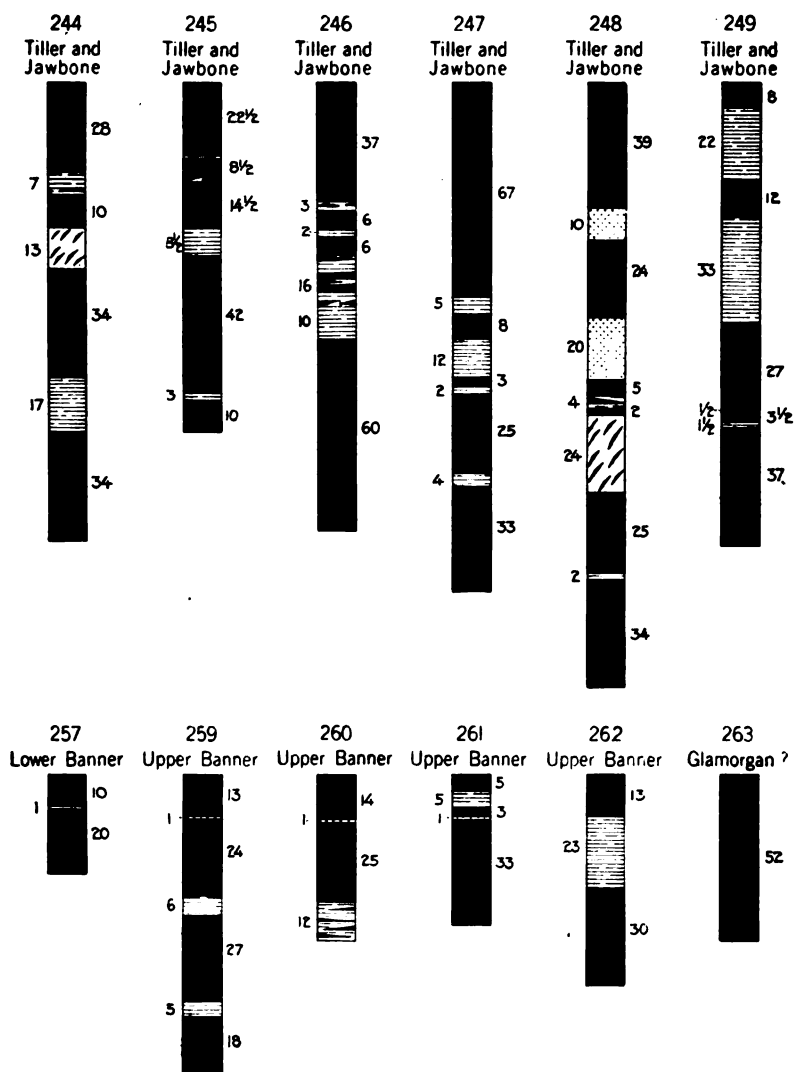


Fig. 13.—Sections of coal beds in the Indian Creek drainage basin.

and comparatively flat top. West of the axis of this anticline beds dip to the northwest and north at about 80 to 400 feet per mile; east of it the general dip is east and southeast at 150 to 550 feet per mile. At the head of Lambert Fork, however, the Lee and older formations have been thrust up over younger rocks along the fault shown on the geologic map and dip southeast at angles of 30° or more. Rocks of Norton age at the mouth of Indian Creek also dip steeply in places and have been buckled and sheared.

The Indian Creek drainage basin contains exceptionally thick coal deposits in parts of the Tiller, Jawbone, and Upper Banner beds, and important deposits at other horizons. (See figs. 3, 4, 5, and 13). In the southern and central parts of the area the Tiller and Jawbone are so close together that they could be mined as one bed containing 7 to 15 feet of coal and underlying a large area. The upper or Jawbone part of the combined beds contains several shale partings and is dirty in places, but even the lower or Tiller part alone is an attractive mining proposition. In the northern and northeastern parts of the area the Tiller and Jawbone are separated by 70 feet or less of shale and sandstone, both beds being thinner than in the districts where they are united. Where the beds are separated the Tiller is the cleanest and thickest, being especially good on part of Lambert Fork and under the ridges north and south of it.

The Upper Banner contains about 5½ feet of excellent coal on Long Ridge, near the head of Cane Creek, and its shale partings are not so thick as to be seriously detrimental. In most other districts the Upper Banner is separated into two parts by an increase in the thickness of one of its partings.

Coal less than 3 feet thick is common at a number of horizons and in many places. Coal beds that are locally 3 to 4 feet thick are the Garden Hole near Sandy Ridge, the Kennedy north of Indian Creek and Lambert Fork, and the Lower Banner near upper Cane Creek. A bed that is tentatively correlated with the Glamorgan is 52 inches thick in an opening at the head of Lambert Fork, but occupies only a small area.

Coal beds lower than the Tiller.—In addition to several thin and unimportant coal beds in the basal part of the Norton formation, there is a fairly persistent bed 30 to 60 feet below the top of the Lee formation. This bed is 28 inches thick in a hollow near the mouth of Lambert Fork (location 241, elevation 1,660 B.), and at least 30 inches thick half a mile north (location 242, elevation 1,530 B.).

Tiller and Jawbone coal beds.—The Tiller lies 800 to 880 feet below the Upper Banner horizon and outcrops low down in all the principal valleys.

Along Cane Creek and its tributaries and the upper part of Indian Creek it combines with the Jawbone coal to form a remarkable bed containing 5 to 15 feet of coal. The upper or Jawbone part of the combined beds contains several layers of shale and other impurities and could not be profitably mined in some localities. There are also layers of "rash", or crushed flaky coal, mixed with more or less shale. Some of the "rash" might be utilized for certain purposes, but most of it is simply waste that would give much trouble in mines. Along Lambert Fork and lower Indian Creek the two beds are too far apart to be mined as one, but the Tiller contains some thick coal along its outcrop south and east of the mouth of Lambert Fork.

The first of the following measurements is a slight modification of one cited by Stone as made in a small mine, now caved, near the forks of Cane Creek. North of this opening the coal separates into two or more thin beds. The second measurement was made at one of two openings a short distance west of the first.

Sections of Tiller and Jawbone coal beds about 1 mile southwest of Duty.

(Location 243, elevation 1,600 B.)

	Ft.	in.
Shale, under sandstone.		
Coal	2	10
Shale	1	7
Bone		5
Coal		7
Shale		3
Coal		5½
Shale and coal	3	1
Coal	2	
Shale	1	9
Coal	2	2½
Coal	8	1
Partings	7	1

(Location 244, elevation 1,565 B.)

	Ft.	in.
Sandstone.		
Coal	2	4
Shale		7
Coal		10
"Rash"	1	1
Coal	2	10
Shale	1	5
Coal	2	10
Coal	8	10
Partings	3	1

Partings are less detrimental to the value of the beds south of the openings just described. The following measurements were made at small strip pits,—the first at the level of Cane Creek and the second near the mouth of Middle Fork. Two openings on the southside of Cane Creek, near these strip pits, are also in 8 or 9 feet of coal with shale partings aggregating 10 to 20 inches:

Sections of Tiller and Jawbone coal beds near forks of Cane Creek.

(Location 245, elevation 1,599 S.)

	Ft.	in.
Shale	3	
Coal	1	10½
Coal, bony in part.		8½
Coal	1	2½
Shale		8½
Coal	3	6
Shale		3
Coal		10
Coal	8	1½
Partings		11½

(Location 246, elevation 1,760 B.)

	Ft.	in.
Shale		
Coal	3	1
Bone		3
Coal		6
Shale		2
Coal		6
Bone, shale, and coal	1	4
Shale		10
Coal	5	
Coal	9	1
Partings	2	7

The coal is at its best on the upper parts of Middle and Left forks of Cane Creek, the following measurements, made at a strip pit less than a mile north of Kiser Gap, being typical:

Section of Tiller and Jawbone coal beds two and one-half miles south of Duty.

(Location 247, elevation 1,790 B.)

	Ft.	in.
Sandstone.		
Coal	5	7
Shale		5
Coal		8
Shale	1	
Coal		3
Shale		2
Coal	2	1
Shale		4
Coal	2	9
Coal	11	4
Partings	1	11

The coal is exceptionally thick along most of Cane Gap Creek, John Fork, and Patton Branch. The proportion of shale in the Jawbone member of the bed is greater near the mouths of those streams, however, and the two members are rather widely separated by shale and sandstone farther south on Indian Creek. The first of the following measurements was made near the head of John Fork, and the second opposite the mouth of that stream:

Sections of Tiller and Jawbone coal beds on John Fork of Indian Creek.

(Location 248, elevation 2,020 B.)

Sandstone.	Ft.	in.
Coal	3	3
Sandstone		10
Coal	2	
Sandstone	1	8
Coal		5
Shale and coal.....		4
Coal		2
"Rash"	2	
Coal	2	1
Shale		2
Coal	2	10
Coal	10	9
Partings		5

(Location 249, elevation 1,820 B.)

	Ft.	in.
Shale	7	
Coal		8
Shale	1	10
Coal	1	
Shale	2	9
Coal	2	3
Shale		$\frac{1}{2}$
Coal		$3\frac{1}{2}$
Shale		$1\frac{1}{2}$
Coal	3	1
Coal	7	$3\frac{1}{2}$
Partings	4	9

The Tiller was found by Stone near the mouth of Puncheon Camp Branch of Lambert Fork (location 250, elevation 1,720), and was reported to be 57 inches thick, including an inch of shale and 3 inches of "rash" near the middle. Half a mile farther up Lambert Fork (location 251, elevation 1,690 S.) the same bed is 32 inches thick. Northwest of the mouth of Lambert Fork the bed is probably thinner.

No full measurement of the Jawbone bed was obtained on Lambert Fork or on lower Indian Creek except in the Indian Creek road near Sullivan Branch (location 252, elevation 1,462 S.), where the coal is 29 inches thick. Blooms and caved pits do not indicate that the Jawbone is very thick where separated from the Tiller.

Garden Hole and associated coal beds.—The Garden Hole coal bed lies about 190 feet above the Tiller and 650 feet below the Upper Banner coal horizon. In the northern part of the area it is in most places only 1 or 2 feet thick, but in the southern part, near Sandy Ridge, it commonly contains 3 to 4 feet of coal with thin shale partings in its middle. The bed has been thoroughly prospected, but most of the prospect pits are caved and are difficult to find because of the position of most of the outcrop on wooded slopes 200 to 400 feet above the principal streams. One pit near the head of Middle Fork of Cane Creek (location 253, elevation 1,955 B.), in the area where the bed is thickest, is reported to be in about 4 feet of coal with a very thin shale parting in the middle.

There are several coal beds between the Garden Hole and the Kennedy, but they are less than 2 feet thick nearly everywhere. One persistent bed is 30 to 50 feet above the Garden Hole and another about 150 feet above the same horizon. It may be the latter bed that is 24 inches thick in the road

near the mouth of Indian Creek (location 254, elevation 1,495 H. L.), but steep dips a short distance north make correlations uncertain. Coal 28 inches thick near the head of Cane Creek (location 255, elevation 1,920 B.) is 143 feet above the Garden Hole in a neighboring boring, and coal of the same thickness near Cane Gap (location 256, elevation 2,280 B.) is at the same stratigraphic horizon. This last measurement was made in a small mine, in which the roof is 8 inches of drab shale under sandstone.

Kennedy coal bed.—The Kennedy lies 300 to 350 feet below the Upper Banner bed and outcrops high in the hills in most of this area. In the southern part of the basin it is only 12 to 24 inches thick, a typical section being at an opening near Cane Creek, $1\frac{3}{4}$ miles southwest of Duty, where 21 inches of coal are overlain by drab sandy shale and a coarse sandstone forms a ledge a few feet below. On the divide north of Indian Creek and Lambert Fork the bed is reported to contain 12 to 48 inches of coal.

Lower Banner coal bed.—The Lower Banner lies about 100 feet below the upper Banner and outcrops only high on the ridges. West and south of the upper part of Cane Creek the thickness of the bed averages between 3 and $3\frac{1}{2}$ feet; elsewhere the coal is thinner. Near the head of Sullivan Branch (location 257, elevation 2,190 B.) the bed is 31 inches thick, including an inch of shale 10 inches from the top. In a spring near the triangulation station at the head of Patton Branch (location 258, elevation 2,440 B.) the coal is 30 inches thick, but blooms elsewhere in this locality indicate a thinner bed at the Lower Banner horizon.

Upper Banner coal bed.—The Upper Banner is an important coal bed in part of the area and outcrops high on the ridges on its western and eastern sides. Under the divide west of the head of Cane Creek the Upper Banner contains an average thickness of $5\frac{1}{2}$ feet of coal, with the characteristic sandstone parting in the upper part and two thicker shale partings in the lower part. On Sandy Ridge at the heads of the eastern tributaries of Indian Creek, the bed is in two parts with less than 3 feet of coal in each, except in a small area between the head of Punccheon Camp Branch and Lambert Fork. Very little is known about the condition of the Upper Banner northwest of the lower part of Cane Creek and west of lower Indian Creek, but the lack of exposures or openings showing thick coal indicates that the bed thins to the north.

The following two sections show the details of the Upper Banner in small mines near the head of Cane Creek. The first measurement was made near the triangulation station on Long Ridge, and the second, which evidently does not include the lower 3 or 4 feet of the bed, at Smith Gap.

Sections of Upper Banner coal bed near head of Cane Creek.

(Location 259, elevation 2,369 C. C. C.)

	Ft.	in.
Sandstone.		
Coal	1	1
Sandstone		1
Coal	2	
Shale		6
Coal	2	3
Shale		5
Coal	1	6
Coal	6	10
Partings	1	

(Location 260, elevation 2,405 B.)

	Ft.	in.
Shale.		
Coal	1	2
Sandstone		1
Coal	2	1
Shale and coal.....	1	
Coal	3	3
Parting		1

The following two measurements were made at openings in which the thickness of coal in one bench is greater than in most places in the district in which they are located. The first section is on a small western tributary of Lambert Fork, a short distance south of the mouth of Cowpen (Copperhead) Branch; the second, which may not include all of the coal, is at the head of Cowpen Branch:

Sections of Upper Banner bed near upper part of Lambert Fork.

(Location 261, elevation 2,339 C. C. C.)

	Ft.	in.
Sandstone.		
Coal		5
Shale		5
Coal		3
Sandstone		1
Coal	2	9
Sandstone.		
Coal	3	5
Partings		6

(Location 262, elevation 2,400 B.)

	Ft.	in.
Sandstone.		
Coal	1	1
Shale	1	11
Coal	2	6
Coal	3	7
Parting	1	11

Splash Dam and higher coal beds.—What may be the Glamorgan bed consists of 52 inches of coal under 3 feet of shale in an opening near the wagon road near the head of Lambert Fork (location 263, elevation 2,358 S.). The outcrop of this bed is very close to the fault which bounds the coal field on the south, so that the area of available coal is small. There is undoubtedly some coal at several other horizons above the Upper Banner, especially in the Splash Dam bed, but no complete measurements were obtained and no thick blooms were seen.

RUSSELL FORK AND SMALL TRIBUTARIES NORTHWEST OF INDIAN CREEK.

Geologic outline.—The area to be considered under this heading includes only the valley of Russell Fork below Indian Creek and the drainage basins of small tributaries not described elsewhere, and is, therefore, a long, narrow strip extending only a short distance back from the river. Rocks exposed include those from near the Garden Hole coal horizon, and perhaps lower, to beds 425 feet above the base of the Wise formation. The strata mapped as undifferentiated Pennsylvanian include chiefly rocks belonging to the part of the Norton formation that is above the Garden Hole horizon, with a few Wise and Gladeville beds in the district north of McClure River. Strata mapped as Gladeville and Wise occur only near the tops of a few ridges. The stratigraphic succession is shown by the generalized columnar sections for the north third of the Clintwood quadrangle and the middle third of the Bucu quadrangle (Pl. IV), by logs of borings in the valley of Russell Fork (Pls. II and III), and by local sections 10, 16, 17, and 20.

The structure of the area is complicated. Beds not mapped as undifferentiated dip, in general, to the northwest and north at very low angles as far north as the axis of the Middlesboro syncline near Pound River. North of the axis they dip to the southeast. Beds mapped as undifferentiated northwest of Sand Lick and the mouth of Lick Creek dip chiefly northeast at high angles, though there are places where there are dips in other directions at all angles up to 90 degrees. The apparent structure in places is that of a monocline dipping steeply to the northeast, but this feature is really subordinate to shearing and buckling along one or more faults parallel to the long axis of the area. This is explained more fully on page 41.

The structure of the beds mapped as undifferentiated southeast of Pawpaw Creek is even more obscure. The beds are nearly level in some places, but in others dip irregularly in different directions. Strata on the southwest have probably been moved past those on the northeast along two vertical or very steep fault planes and have been more or less buckled and folded during the process. One of these faults extends from Indian through a point a short distance north of Abners Gap, and the other from near Indian to a point northwest of Murphy. The irregular dips on Russell Fork between Fox and Pawpaw creeks were probably caused by buckling without faulting.

The area has only a few thick coal deposits. (See figs. 3 and 14.) Coal beds included among the rocks mapped as undifferentiated Pennsyl-

vanian are nearly all thin and are commonly crushed and fractured so that they could not be mined with profit. Beds below the Kennedy horizons are exposed in only a small area and are less than 2 feet thick. The Kennedy is thin in most places, though locally 3 or 4 feet thick. The Lower and Upper Banner are both less than 2 feet thick, so far as now known, and are lacking in places. The Splash Dam bed is thin in most places, but contains about 3½ feet of coal north of McClure River and Russell Prater Creek. The Hagy is persistent in the northwestern part of the area, but is not more than 2 feet thick. The Glamorgan, Lyons, and Blair beds con-

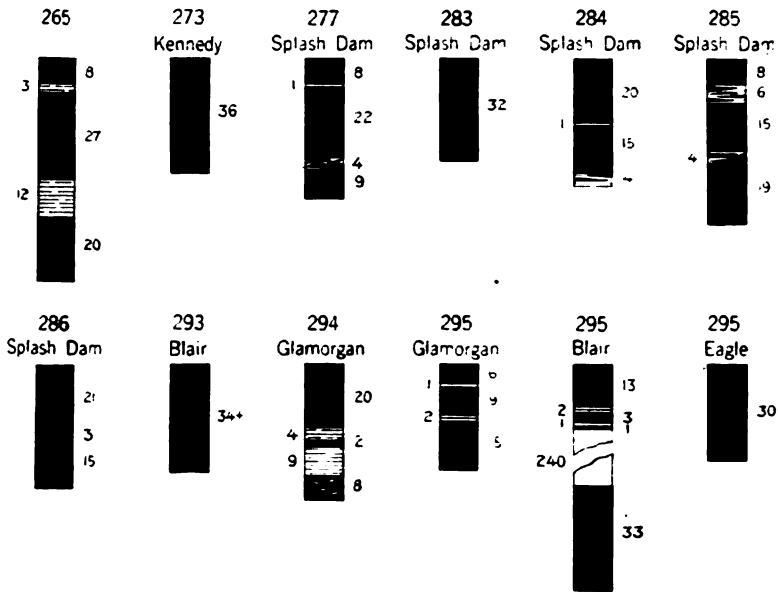


Fig. 14.—Sections of coal beds on and near Russell Fork northwest of Indian Creek.

tain 2 or 3 feet of coal in the small areas in which they have escaped erosion, but commonly include several shale partings. The Eagle bed is 2 to 5 feet thick, but no coal was found at the Clintwood or higher horizons.

Outcrops not correlated.—Thin and moderately thick coal beds were seen in a number of places within the areas mapped as undifferentiated Pennsylvanian. The occurrence in these areas of irregular dips, indicating buckling and possible faulting, makes it unsafe to assign these exposures to any definite bed, though the approximate stratigraphic position of many may be ascertained.

A coal bed that is at least 16 inches thick is exposed in the road southwest of the mouth of Pound River (location 264, elevation 1,669 S.) and may be the Glamorgan. What may be the Lyons bed is 23 inches thick a short distance up the road (elevation 1,705 B.), and a 2-foot bed of doubtful stratigraphic position was seen northeast of location 264 (elevation 1,565 B.). Steep dips in different directions may be seen along the road on both sides of these outcrops, involving several coal blooms. The following measurement of a bed that resembles the Splash Dam was made in a western tributary of Russell Fork, north of Hill School. The bed is nearly level where measured, but strata in other parts of the hollow dip more or less steeply, chiefly to the east or northeast.

Section of coal bed one and one-fourth miles south of mouth of Pound River.

(Location 265, elevation 1,500 B.)

	Ft.	in.
Coal		8
Shale		3
Coal	2	3
Shale	1	
Coal	1	8
Shale, compact	1	6
Coal	4	7
Partings	1	3

Stone states that coal about 4 feet thick was reported at a caved pit just south of Sand Lick, by the wagon road (location 266, elevation 1,355 S.). Strata associated with this coal bed, which is probably the Kennedy, dip at an angle of about 7° in a neighboring exposure. Farther down Russell Fork, at the mouth of Duty Branch (location 267, elevation 1,284 H. L.), there are 18 to 24 inches of slightly impure and crushed coal. There appears to be a fault at the side of this opening and beds dip steeply northeast for a few rods up Duty Branch. A few yards behind the house at the mouth of Duty Branch coal 16 inches thick dips 23° to the N. 65° E.

There are only a few uncorrelated coal exposures, probably of beds between the Tiller and Kennedy horizons, in the areas mapped as undifferentiated Pennsylvanian along Russell Fork between Pawpaw and Indian creeks. One of these is at the sharp bend in Russell Fork south of Murphy (location 268, elevation 1,456 S.), where there are 18 inches of coal with a sandstone roof. There are 16 inches of coal, dipping southeast, in the road on the north side of the river at Indian (location 269, elevation 1,440 B.). A coal bed 23 inches thick outcrops beside the same road just south of Murphy (location 270, elevation 1,403 H. L.).

Garden Hole and associated coal beds.—The Garden Hole bed is below stream levels in most of this area, but is exposed in the lower part of Abners Branch, which heads near Abners Gap. It has been opened at a few places along the logging tramway near Bee (location 271, elevation 1,483 H. L.), where it is 3 to 26 inches thick, has a roof of 4 feet of blue to drab shale under sandstone, and dips slightly down the branch.

As shown by blooms and a few caved pits, there are at least 2 thin coal beds between the Garden Hole and Kennedy horizons. The only complete measurement obtained was at Abners Gap (location 272, elevation 1,550 B.), where a 22-inch coal bed about 150 feet below the Kennedy horizon is overlain by 2 feet of blue to drab shale under sandstone.

Kennedy coal bed.—The Kennedy horizon is about 300 feet below that of the Upper Banner in the area in which it is exposed. It is irregular in thickness and probably thin in most places, though it is locally as much as 4 feet thick. A short distance west of Murphy (location 273, elevation 1,589 S.) the coal is 3 feet thick and has 4 feet of irregularly bedded shale in the roof. The coal is at least 30 inches thick near the mouth of Laurel Branch, in a pit beside the road (location 274, elevation 1,336 S.), where it lies on a very coarse sandstone that outcrops conspicuously along this part of Russell Fork. The bed is reported to be 42 inches thick in a pit on the west side of the river a mile southeast of Sand Lick, and to be slightly thicker at Sand Lick, as previously mentioned.

Lower and Upper Banner coal beds.—Both the Lower and Upper Banner coal beds are thin in this area and may be lacking in a large part of it. The Lower Banner was measured only in a pit near stream level in the upper part of Laurel Branch (location 275, elevation 1,547 S.), where it is 19 inches thick. The Upper Banner was seen only by a path on the spur north of Lazarus Branch (location 276, elevation 1,580 B.), where what is probably only one bench of a split bed is about 15 inches thick.

Splash Dam coal bed.—The Splash Dam coal lies 40 to 100 feet above the Upper Banner horizon and only a few feet above a massive sandstone that makes conspicuous ledges and cliffs. It is probably thin southeast of the mouth of Fryingpan Creek, but northwest of that place there are many openings showing $1\frac{1}{2}$ to 4 feet of coal. The bed is at its best north of Russell Prater Creek, where the average thickness of coal is about $3\frac{1}{2}$ feet. Where the coal is thick there are commonly a few very thin shale partings and a characteristic layer of very hard, slightly bony coal.

The Splash Dam is exposed at railroad level 1 mile north of McClure River (location 277, elevation 1,267 S.) and was utilized in railroad con-

struction work. In small drifts the bed is 44 inches thick, including an inch of shale 8 inches from the top and a slightly bony layer in the lower part. The floor is shale that is carbonaceous at the top and the roof is 20 feet of blue shale that grades into an overlying sandstone.

The Splash Dam is 18 to 24 inches thick at four openings in different western tributaries of Russell Fork between McClure River and Lick Creek. The pit farthest north (location 278, elevation 1,670 B.) contains 19 inches of coal, including at the top 5 inches of impure cannel over an inch of bony coal.

In the part of the area that lies east of Russell Fork, the coal is at least 18 inches thick on a tributary of Tilda Anderson Branch (location 279, elevation 1,645 B.), 21 inches thick east of Sand Lick (location 280, elevation 1,640 B.), 18 inches half a mile north of the village (location 281, elevation 1,655 B.), and 19 inches opposite the mouth of Lazarus Branch (location 282, elevation 1,525 B.). At the pit last mentioned a thin layer of cannel coal caps the bed as at location 278, and the roof is a blocky black shale at all pits near Sand Lick.

The Splash Dam coal is 32 inches thick in a pit opposite the mouth of McClure River (location 283, elevation 1,400 B.), and about 44 inches in another a short distance north. At a small mine half a mile north of location 283 (location 284, elevation 1,350 B.), the bed is 40 inches thick, including an inch of coaly shale in the middle and 4 inches of worthless coal and shale at the base. The bed has about the same thickness for nearly 2 miles north of the mouth of Russell Prater Creek and then disappears beneath the river because of a gentle northward dip. Its horizon is plainly marked by a massive 60-foot sandstone the top of which is 5 or 10 feet below the coal. At the tunnel $2\frac{1}{4}$ miles from the mouth of the Russell Prater, the coal again appears at river level and has been mined for railroad construction purposes. The dip at the mouth of the drift is 18° NE. and a measurement of the bed is as follows:

Section of Splash Dam coal bed at tunnel south of Barts Lick Creek.

(Location 285, elevation 1,210 B.)

	Ft.	in.
Sandstone, massive at top, thin-bedded at base.....	20	
Shale	1	
Coal		8
Coal in some places, "rash" and shale in others.....		6
Coal	1	3
Bone		4
Coal	1	7
Coal	4	
Parting		4

The coal is below river level from the north end of the tunnel to the splash dam just below the mouth of Pound River, where a northward rise causes it to reappear. Measurements in a pit at railroad level 50 feet north of the dam and at a small mine a short distance farther north and 90 feet higher (location 286, elevation 1,300 C. C. C.) show 37 to 39 inches of coal, including a 3-inch, slightly bony layer 21 inches below the top. The roof is 6 feet of sandy shale under sandstone, and the thick massive sandstone bottom-rock is only 2 feet below the coal.

Hagy coal bed.—The Hagy coal bed is commonly 100 feet above the Splash Dam and is 2 feet or less thick. It lies a few feet above a massive sandstone that makes more or less conspicuous ledges and commonly has a blue shale roof that is overlain by a thin bed of sandstone. Four measurements were made east of Russell Fork in Dickenson County, but only thin blooms were found elsewhere.

The Hagy is 24 inches thick at the head of the right fork of Tilda Anderson Branch (location 287, elevation 1,700 B.) and 19 inches on a left fork (location 288, elevation 1,740 B.). The coal is 18 inches thick at the end of the tunnel south of Barts Lick Creek (location 289, elevation 1,260 B.), and is exposed in railroad cuts from the tunnel to a few rods beyond the creek (location 290, elevation 1,245 B.), where it is 23 inches thick.

Coal beds in Wise formation.—There are four coal beds in the lower 200 feet of the Wise formation: The Glamorgan near the base, the Lyons 20 to 40 feet higher, the Blair about 100 feet above the Glamorgan, and the Eagle 50 to 90 feet above the Blair. These beds contain 2 or 3 feet of coal in most places, but underlie only small areas near the tops of a few ridges and will not be described separately.

The Lyons bed is 23 inches thick $1\frac{1}{2}$ miles southwest of the mouth of Pound River (location 291, elevation 1,880 B.), and the Glamorgan is about the same thickness at the neighboring road corner, though split into two parts by shale.

In the ridge road $1\frac{1}{2}$ miles northeast of Sand Lick (location 292, elevation 1,951 S.) the Glamorgan is at least 34 inches thick, as is also the Blair at the head of the right fork of Tilda Anderson Branch (location 293, elevation 2,040 B.).

The first of the following measurements of the Glamorgan was made at a small mine above the tunnel south of Barts Lick Creek, and the second in a small hollow a few rods north of the mouth of the creek.

Sections of Glamorgan coal bed on Russell Fork near Barts Lick Creek.

Location 294, elevation 1,435 B.)			(Location 295, elevation 1,420 B.)		
	Ft.	in.		Ft.	in.
Sandstone	20		Sandstone.		
Shale	1		Slate, thin.		
Coal	1	8	Coal		6
Clay		4	"Rash"		1
Coal		2	Coal		9
Clay		9	Shale		2
Coal, impure		8	Coal	1	3
Coal	2	6	Coal	2	6
Partings	1	1	Partings		3

In the hollow in which the last section was measured several higher beds are exposed. The Lyons coal (elevation 1,455 B.) is 20 inches thick, with two coal streaks in the thin shale roof. The lower bench of the Blair is 33 inches thick (elevation 1,550 B.), and the upper bench is about 20 feet higher and contains only 13 inches of coal that could be utilized. The Eagle bed (elevation 1,630 B.) is 30 inches thick. Because of rather steep dips and an error in the topographic map that makes locations uncertain, the elevations of these beds do not furnish a means of calculating the exact intervals between them.

RUSSELL FORK AND ALL TRIBUTARIES EAST OF INDIAN CREEK.

Geologic outline.—The part of the Russell Fork drainage basin that lies east of Indian and the mouth of Indian Creek includes exposures of nearly all the Norton formation, the Gladeville sandstone, and the lower 300 feet of the Wise formation. The Pennsylvanian rocks in a narrow strip extending from northwest to southeast near Russell Fork are not differentiated on the accompanying geologic map, but probably include only the Norton and Gladeville, the latter only at the southeast end of the area. Elsewhere the Gladeville has been removed by erosion except on two small knobs on Fletcher Ridge and in a small area near Big A Mountain. The Wise formation remains only near Big A. The stratigraphy of the greater part of the Pennsylvanian series is shown graphically by the columnar section of the middle third of the Bucu quadrangle (Pl. IV). Exposed rocks are also shown in local sections 13, 14, and 15.

Formations in which there are commercially important coal beds are exposed only northwest of a great thrust fault, southeast of which the surface strata are all pre-Pennsylvanian and contain no workable coal.

There is also a fault, probably nearly vertical, from the north end of Big A Mountain to Indian and beyond, and strata for a short distance on each side of it dip so irregularly in places that no attempt has been made to map coal beds or to indicate the exact structure. Beds south of this fault have been shoved to the northwest past those north of it and have been folded into an arch here named the Sourwood Mountain anticline. Dips east of this anticline are chiefly to the east and those west of it to the west. North

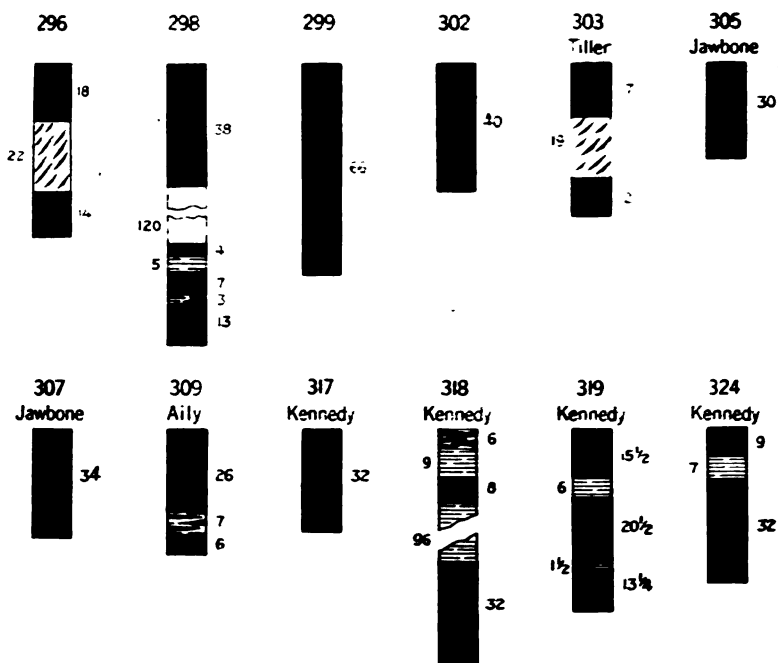


Fig. 15.—Sections of coal beds in the Russell Fork drainage basin east of Indian Creek.

of Russell Fork there is a low, broad arch at the west end of the Dry Fork anticline. Strata are almost horizontal near this arch and dip very gently to the northwest on one side of it and to the south and southeast on the other.

The thickest coal beds in the area are the Tiller, Jawbone, and Kennedy. (See figs. 4 and 15.) Other coal beds are less than 3 feet thick nearly everywhere and are very thin or lacking in some districts. The Tiller contains 2 to 4 feet of coal near Council, but is split by a thick shale and

"rash" parting. The Jawbone coal is 2 to 6 feet thick and could be profitably mined in some localities. The Kennedy is 18 to 50 inches thick and is the bed that is being mined at Drill, on Lewis Creek. There are only a few openings in part of the area, and the reader is referred to the descriptions of pits near the heads of Garden and Prater creeks for additional information concerning beds underlying Winding and Fletcher ridges.

Outcrops not correlated.—The rocks along and near Russell Fork that are mapped as undifferentiated Pennsylvanian include several coal beds and there are many prospect pits in coal 1 to 5 feet thick. Most of these pits are on the slopes facing Russell Fork on its south side and are chiefly in the Tiller and Jawbone beds. The presence of one or more faults and of steep and irregular dips in parts of this district makes it inadvisable to attempt to make exact correlations.

Coal in a small mine southeast of Davenport (location 296, elevation 1,690 B.) is directly overlain with a thick bed of coarse sandstone containing a few pebbles and has the characteristics of the Tiller bed. There are 22 inches of "rash" in the middle, with 18 inches of coal above it and 14 inches below. Another opening in the same neighborhood (location 297, elevation 1,575 B.) is in 30 inches of coal under a sandstone cap like that just mentioned. There are several exposures and pits near the mouth of Carroll Presley Branch, one of which shows coal 30 inches thick at an elevation of 1,730 feet, and another 22 inches of coal at an elevation of 1,600 feet. The following measurements were made at a pit a short distance west of the two just mentioned:

Section of coal beds on Carroll Presley Branch.

(Location 298, elevation 1,750 B.)

Shale.	Ft.	in.
Coal	3	2
Concealed	10	
Coal		4
Clay shale		5
Coal		7
Shale and coal		3
Coal	1	1

A clean bed of coal 66 inches thick was seen half a mile southwest of Council (location 299, elevation 2,085 B.). A few feet of shale that forms the roof is overlain by 50 feet of sandstone. Coal at least 28 inches thick lies under a thinner sandstone bed half a mile south of Council (location 300, elevation 1,900 B.).

Only a few prospect pits in what appeared to be thin beds were found among the strata mapped as undifferentiated Pennsylvanian on the north side of Russell Fork. One bed is about 2 feet thick near Indian (location 301, elevation 1,450 B.).

Coal beds lower than the Tiller.—The only correlated coal exposure found below the Tiller horizon is near the level of Russell Fork half a mile southeast of the mouth of Hurricane Creek (location 302, elevation 1,503 S.), where there is a clean bed 40 inches thick and about 170 feet below the Tiller. Only sandstone shows at the coal horizon a short distance from the prospect pit.

Tiller coal bed.—The Tiller lies about 830 feet below the Splash Dam horizon and a few feet below a coarse, siliceous sandstone containing quartz pebbles. The coal is below stream levels except near Russell Fork and is 2 to 4 feet thick. A thick parting of impure coal and shale ("rash") in the middle of the bed greatly impairs its commercial value.

The Tiller has been opened at many places near Council and is well exposed in a mine a few feet above the level of Russell Fork less than half a mile southeast of the village (location 303, elevation 1,686 S.). In this district the bed is in two benches separated by 19 to 36 inches of shale and a mixture of crushed coal and shale. The upper bench of coal is 12 to 18 inches thick and the lower bench is 9 to 22 inches thick. In one pit on Tiller Branch at Council the shale and impure coal parting is 5 feet thick.

Jawbone coal bed.—The Jawbone coal is 30 to 90 feet above the Tiller and only a few feet above the conglomeratic sandstone cap-rock of the latter bed. The Jawbone coal is clean in most places and is 2 to about 6 feet thick. The roof of the coal is a blue shale overlain by medium-grained sandstone.

The Jawbone is at least 22 inches thick by the wagon road up the right fork of Russell Fork (location 304, elevation 1,740 B.), and is 30 inches thick on Tiller Branch, north of Council (location 305, elevation 1,720 B.), where it is 60 feet above a pit in the Tiller bed. The coal is reported to be more than 3 feet thick at an abandoned mine on Dry Pen Branch (location 306, elevation 1,660 B.). A small mine on Russell Fork west of Dry Pen Branch (location 307, elevation 1,680 B.) is in a bed that is either the Jawbone or about 35 feet higher and is 34 inches thick. A partially caved pit in the Jawbone in a small hollow nearly a mile east of Davenport (location 308, elevation 1,645 B.) is in coal 5 or 6 feet thick. Shale occupies the position of the lower part of this coal near Davenport.

Garden Hole and associated coal beds.—The Garden Hole bed is 600 to 675 feet below the Splash Dam horizon. There are several coal beds between it and the Kennedy, one being 50 to 100 feet above it and another, the Aily, about 100 feet higher. Each of these coals is only a few inches to about 36 inches thick, but, because they are exposed low down in the principal valleys, they are used to supply local needs in a few places.

The only correlated exposure of these beds south of Russell Fork is at a pit in the Aily on McFarlan Branch (location 309, elevation 1,985 B.). The coal is 39 inches thick, including 7 inches of impure coal and shale near the bottom, and lies under 80 feet of coarse sandstone that forms the bottom-rock of the Kennedy bed.

The Garden Hole bed is about 30 inches thick in two pits near the mouth of Sycamore Fork and only 15 inches a short distance north, 20 feet above the railroad track up Grissen Creek (location 310, elevation 1,850 B.). A mile farther up Grissen Creek (location 311, elevation 2,070 B.) a coal bed 24 inches thick and 100 feet above the Garden Hole horizon is 65 feet above the stream. The same bed is 19 to 27 inches thick on Harris Fork (location 312, elevation 1,995 B.), and has a roof of 2 feet of clay shale under sandstone.

The Garden Hole and associated beds are exposed low down in the valleys of both forks of Hurricane Creek. The Garden Hole bed has been opened beside the road up Rockhouse Branch of the right fork (location 313, elevation 1,723 S.), where it is 22 to 25 inches thick and lies under 9 feet of blue shale that grades upward into sandstone. The coal is reported to be about the same thickness in pits farther north on Hurricane Creek, but only 16 inches of what may not be a complete exposure shows in the road near the mouth of this fork (location 314, elevation 1,601 S.). Half a mile west (location 315, elevation 1,530 B.), the coal is 19 inches thick and underlies 7 feet of blue shale. The Garden Hole is reported to be slightly thicker in pits farther north. No complete measurements of the coal beds between the Garden Hole and Kennedy horizons were obtained in the Hurricane Creek drainage basin, but the Aily was reported 2 to 3 feet thick at a few caved pits.

Kennedy coal bed.—The Kennedy is 300 to 380 feet below the Splash Dam coal horizon and its outcrop, even on wooded slopes, may be easily found because of its position a few feet above a coarse-grained, cliff-making sandstone and under nearly 200 feet of shale and rather fine-grained sandstone that make long gentle slopes. The bed is about 18 to 50 inches thick, the average being about 2 feet in the Hurricane drainage basin and nearly 3 feet elsewhere.

The Kennedy makes a conspicuous bloom in the wagon road at the head of Russell Fork, and 25 inches of coal is exposed near it and 25 feet higher stratigraphically (location 316, elevation 2,215 B.). The Kennedy is clean and 32 inches thick at the head of Grissen Creek, and shows plainly in a railroad cut (location 317, elevation 2,290 B.), the roof being a few feet of sandy shale under thin-bedded sandstone and the floor of sandstone. The first of the following measurements was made near the head of Harris Fork and the second in a pit beside the road up Tiller Branch, half a mile north-east of Council.

Sections of Kennedy coal bed on Harris Fork and Tiller Branch.

(Location 318, elevation 2,115 B.)

	Ft.	in.
Shale, blue	10	
Coal, dirty		6
Shale		9
Coal		8
Shale	8	
Coal	2	8
Coal	3	10
Partings	8	9

(Location 319, elevation 2,142 S.)

	Ft.	in.
Shale	4	
Coal	1	3½
Clay		6
Coal	1	8½
Clay		1½
Coal	1	1¼
Coal	4	1¼
Partings		7½

The coal is about 2 feet thick and overlain by 5 feet of sandy shale on the east side of the principal fork of Hurricane Creek (location 320, elevation 1,915 B.), and is 25 inches thick in two pits near the head of the same fork (location 321, elevation 1,880 B., and location 322, elevation 1,990 B.). Less than half a mile from the pit last mentioned (location 323, elevation 1,960 B.) the coal is in two benches separated by 56 inches of shale, the lower bench being 18 inches thick and the upper 8 inches. Near the head of the left fork of Hurricane Creek (location 324, elevation 1,815 B.), where the bed has a sandy shale roof and a sandstone floor, an upper bench of coal 9 inches thick and a lower bench 32 inches thick are separated by 7 inches of carbonaceous shale. On a tributary 2½ miles southwest (location 325, elevation 1,785 B.) the coal is only 24 inches thick.

Lower and Upper Banner coal beds.—The Lower Banner horizon is 110 to 200 feet above that of the Splash Dam. The coal is 2 to 3 feet thick near Grissen Creek and other streams at the head of Russell Fork, but is probably thinner elsewhere in this area. The only complete measurement obtained was in a railroad cut near the head of Grissen Creek (location 326, elevation 2,470 B.), where the coal is 28 inches thick and is overlain by shale and underlain by at least a foot of clay resting on sandstone. The Upper

Banner coal bed lies about half way between the Lower Banner and the Splash Dam horizons and appears to be very thin in all or most of the area.

Splash Dam and higher coal beds.—The Splash Dam coal outcrops well up on the principal ridges and is not well exposed in many places. It lies a few feet above a massive sandstone that forms the cap-rock of the Upper Banner coal bed and contains many pebbles on the ridge northeast of Indian, as well as a few in some other localities. There is a large proportion of sandstone between the coal and the top of the Norton formation, most of it being coarse, friable, and brownish.

At the three places measured the coal is 22 to about 36 inches thick and it is not likely to be much thicker elsewhere. In a pit at the north end of Big A mountain (location 327, elevation 2,610 B.) the coal is 30 or 36 inches thick. At least 3 feet of coal bloom shows in the road on Fletcher Ridge, at the head of Hurricane Creek (location 328, elevation 2,395 B.), with about 2 feet more 15 feet higher and a thinner bed 25 feet lower. Near the head of New Camp Branch of the left fork of Hurricane Creek (location 329, elevation 2,065 B.) the bed is only 23 inches thick, including an inch of shale 5 inches from the bottom.

There are several coal beds above the Splash Dam in this area, but none was measured except a 14-inch bed that lies 60 feet below the Gladeville sandstone on the high knob on Fletcher Ridge. The Hagy bed, which is 100 feet above the Splash Dam, may be 2 or 3 feet thick in the Hurricane Creek drainage basin, and there may be several moderately thick coal beds in the small area in which the Wise formation is exposed near Big A Mountain.

LITTLE FOX, FOX, PAWPAW, AND LITTLE PAWPAW CREEKS.

Geologic outline.—The exposed beds of this area embrace those from about 100 feet below the Kennedy coal horizon to those 350 feet above the base of the Wise formation. The stratigraphic succession is much the same as that shown by the average intervals in the graphic columnar section for the north third of the Bucu quadrangle (Pl. IV). Details are shown in local sections 16, 17, and 25. Rocks mapped as undifferentiated Pennsylvanian at the mouths of the Pawpaw creeks are of Norton age, but dip so irregularly in places that no attempt has been made to show the exact position of coal beds. Outside this area of irregular dips, the structure is simple and dips are to the northwest nearly everywhere.

Very few prospect pits have been opened in this area and little is known about its coal resources. All coal exposures found in the Norton formation are less than 30 inches thick, but pits in neighboring areas indicate that the Hagy bed may be 3 or 4 feet thick near the heads of Fox and Pawpaw creeks. The coal beds in the lower 200 feet of the Wise formation are fairly thick, but underlie only small areas near the ridge tops, and all except the Eagle contain several shale partings. The Glamorgan and Blair beds contain coal layers aggregating 2 to 3 feet thick and the Eagle bed is 3 to possibly 5 or 6 feet thick. (See fig. 5.)

Kennedy coal bed.—The Kennedy is 325 to 370 feet below the Splash Dam horizon and outcrops only near the bottoms of the principal valleys. Although the coal is only about 2 feet thick, it is mined in a number of pits for family use. The bed is commonly overlaid and underlain by shale, and there is coarse-grained sandstone 5 to 15 feet below it.

The Kennedy is 23 inches thick in a pit on the upper part of Little Fox Creek (location 330, elevation 1,630 B.) and 25 inches on the lower part (location 331, elevation 1,480 B.). It is 2 feet thick in two small mines near the mouth of Fox Creek (locations 332 and 333, elevation 1,420 B.). The coal is 28 inches thick a little farther up the creek (location 334, elevation 1,433 S.), but the top 6 inches are slightly impure and slickensided. A pit on Pawpaw Creek (location 335, elevation 1,390 B.) is in coal only 22 inches thick.

Coal beds above the Kennedy.—So few openings were found in beds higher than the Kennedy that little can be said as to their general characteristics. It seems very probable, however, that all beds in the Norton formation contain coal less than 2 feet thick except in small areas. The following generalizations can be made from measurements made in neighboring parts of the Russell Prater and Prater Creek drainage basins. The Hagy coal, which is about 100 feet above the Splash Dam horizon, may be 3 or 4 feet thick near the heads of Pawpaw and Fox creeks. The Eagle bed, which is about 160 feet above the base of the Wise formation and directly under a thick sandstone, is 3 to 6 feet thick at the head of Pawpaw Creek. The Blair coal, 50 feet below the Eagle, is probably 2 or 3 feet thick.

Traces of the Lower and Upper Banner coal beds were found only on Pawpaw and Little Pawpaw creeks, and the only complete measurement was of the Upper Banner on the former stream (location 336, elevation 1,660 B.), where it is 25 inches thick, including 5 inches of clay, and lies 80 feet below the Splash Dam horizon. The Splash Dam bed contains 30 inches of coal on the upper part of Fox Creek (location 337, elevation 1,800 B.),

split in the middle by shale 10 inches thick. The Hagy bed is reported to be 2 feet thick at the head of Little Pawpaw Creek (location 338, elevation 1,695 B.), and may be slightly thicker. The Blair bed is 30 inches thick near the head of Little Pawpaw Creek (location 339, elevation 2,080 B.). The Eagle has the following section on the ridge south of Pawpaw Creek:

Section of Eagle coal bed near head of Pawpaw Creek.

(Location 340, elevation 2,190 B.)

	Ft.	in.
Clay, under sandstone.....	1	2
Coal		11
Shale		3
Coal	1	4
Bone		1½
Coal	1	4½
Coal	3	7½
Partings		4½

RUSSELL PRATER AND BARTS LICK CREEKS.

Geologic outline.—Beds exposed in the drainage basins of Russell Prater and Barts Lick creeks include those from 140 feet below the Splash Dam coal horizon to 500 feet above the base of the Wise formation. The stratigraphy is shown by the generalized columnar sections for the north thirds of the Clintwood and the Bucu quadrangles (Pl. IV), by logs of borings in the northeast corner of the Clintwood quadrangle (Pl. II), and by local sections 18, 19, 20, and 24. Dips are low and their direction is governed chiefly by the Middlesboro syncline, the axis of which extends from southwest to northeast in the Barts Lick Creek drainage basin. In the small area north of this axis beds dip southeast, and elsewhere to the northwest or west. A short but well-defined syncline, whose axis corresponds closely to the position of War Fork of Russell Prater Creek, causes southwesterly dips in a small area, and there are a few other minor structural irregularities.

The area contains some coal deposits that afford possibilities of profitable extraction in the near future. (See figs. 5 and 16.) The Upper Banner bed, which is thick in many localities farther south and southwest, is only a few inches thick in this part of the field. The Splash Dam bed contains about 3 feet of coal along the lower part of Russell Prater Creek, but splits to the east. The Hagy bed is about 2 feet thick along Barts Lick Creek and the lower part of Russell Prater Creek, and thickens to the east, reach-

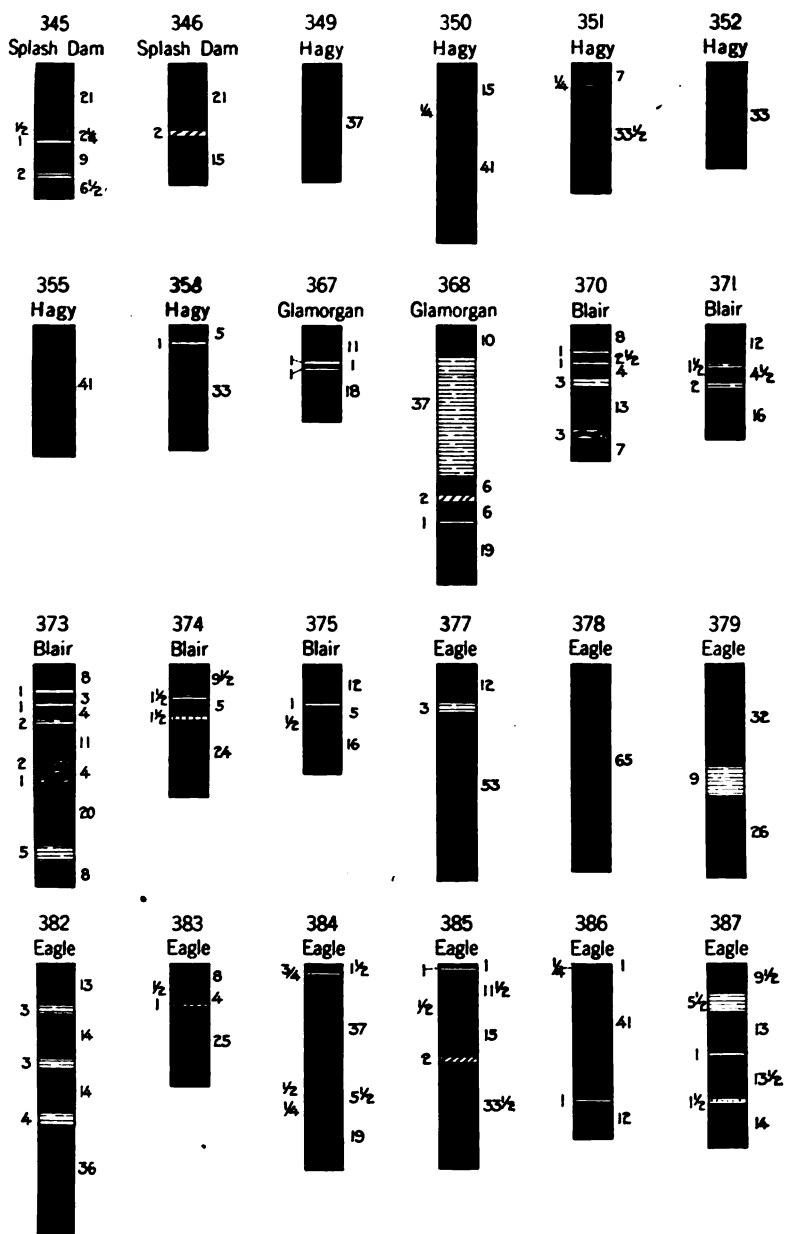


Fig. 16.—Sections of coal beds in the drainage basins of Russell Prater and Barts Lick creeks.

ing a maximum of nearly 5 feet in an opening on War Fork. The Glamorgan, Lyons, and Blair beds are thin in many places and contain several layers of shale. Locally, however, the layers of coal are as much as $3\frac{1}{2}$ feet in aggregate thickness in the Glamorgan bed and $5\frac{1}{2}$ feet in the Blair bed.

The Eagle bed would be by far the most valuable bed in the area if it were not for the fact that it underlies only small areas near the ridge tops. It contains coal 4 to 5 feet thick on both side of most of Russell Prater Creek and its tributaries, and includes few partings that would give trouble in mining. The Clintwood and Campbell Creek beds have not been found in the small areas in which they might outcrop near the tops of some ridges, though the Clintwood is about 4 feet thick a short distance north of the eastern part of the Russell Fork drainage basin.

Splash Dam coal bed.—The Splash dam bed lies a few feet above a massive sandstone and is exposed a short distance above stream level along Russell Prater Creek from its mouth nearly to the head of the left fork and of War Fork. The bed contains about 3 feet of coal with only thin shale partings along the lower part of Russell Prater Creek, but at and east of the mouth of Greenbrier Creek it is split by thin shale beds into two or three parts, none of which is more than 2 feet thick.

Half way between the mouths of Greenbrier Creek and War Fork, in a spring beside the road (location 341, elevation 1,462 S.), what is probably the thickest bench of the Splash Dam includes 16 inches of coal and an inch of shale and is overlain by 5 inches of black shale under sandstone. The roads east of this and up both forks of Russell Prater Creek cross the Splash Dam bed many times. One bench, capped by 7 feet of shale, is 23 inches thick near the head of War Fork (location 342, elevation 1,700 B.). Three benches, each separated from the other by 10 feet of shale, are exposed in the road half a mile north of Prater, the upper bench (location 343, elevation 1,530 S.) being 19 inches thick, and the other two not measurable. The lower bench is 19 inches thick, including an inch of shale, in a pit between Prater and the exposure just mentioned, and the upper bench is 21 to 24 inches thick in several exposures farther northeast. The middle bench, however, is probably very thin. The coal is in two benches 16 feet apart near the mouth of Greenbrier Creek, as shown in a road cut (location 344, elevation 1,410 B.) in which the lower bench is 16 inches thick and the upper is 17 inches.

The coal is thicker and probably in only one bench on the lower part of Russell Prater Creek, as shown by the following measurements, the first made at a small mine near the road between Russell Prater and Barts Lick creeks and the second at an exposure a short distance west. An analysis of the coal at the mine is given in another part of this report.

Sections of Splash Dam coal bed on lower Russell Prater Creek.

(Location 345, elevation 1,378 S.)

	Ft.	in.
Shale	3	
Coal	1	9
Shale		$\frac{1}{2}$
Coal		$2\frac{1}{4}$
Shale		1
Coal		9
Shale		2
Coal		$6\frac{1}{2}$
Coal	3	$2\frac{3}{4}$
Partings		$3\frac{1}{2}$

(Location 346, elevation 1,355 B.)

	Ft.	in.
Shale	4	
Coal	1	9
"Rash"		2
Coal	1	3
Coal	3	
Partings		2

A short distance down the creek (location 347, elevation 1,381 C. C. C.) the bed is 29 inches thick, with only a few streaks of impurities.

Hagy coal bed.—The Hagy coal is 60 to 120 feet above the Splash Dam bed, the average distance being about 100 feet. It has a sandstone bottom-rock that is slightly thinner than that of the Splash Dam and is characterized by a roof of deep blue shale. The bed is exposed low in the valley of Russell Prater Creek from its mouth nearly to the heads of the principal branches and also along the lower part of Barts Lick Creek. The coal is only 15 to 26 inches thick along Barts Lick Creek and Russell Prater Creek west of Prater, but is 2 to $3\frac{1}{2}$ feet thick along Greenbrier Creek and the left fork of Russell Prater and $2\frac{1}{2}$ to $4\frac{1}{2}$ feet along War Fork and its tributaries. The bed is clean, shale partings being very thin in some localities and absent from others.

A caved pit in a small tributary south of Prater School (location 348, elevation 1,585 B.) is in coal at least 2 feet thick. Three miles east of this, on a southern tributary of War Fork (location 349, elevation 1,730 B.), the coal is 37 inches thick. The following two sections near the heads of War Fork, the first at Larkin Owens's on the right branch of the stream, and the second on the left branch, show the bed at its best:

Sections of Hagy coal bed on War Fork of Russell Prater Creek.

(Location 350, elevation 1,810 B.)

	Ft.	in.
Shale	8	6
Coal	1	3
Shale		$\frac{1}{4}$
Coal	3	5
Coal	4	8
Partings		$\frac{1}{4}$

(Location 351, elevation 1,810 B.)

	Ft.	in.
Shale	4	
Coal		7
Shale		$\frac{1}{4}$
Coal	2	$9\frac{1}{2}$
Coal	3	$4\frac{1}{2}$
Partings		$\frac{1}{4}$

The coal is 33 inches thick on Bear Branch of War Fork (location 352, elevation 1,760 B.) and about the same on Laurel Branch. Coal 30 inches thick was reported in the hollow back of Prater store (location 353, elevation 1,660 B.). The coal is 32 inches thick in one pit near the road at the head of the left fork of Russell Prater Creek (location 354, elevation 1,722 S.), the upper part being very impure, and at another pit is 41 inches thick, including three streaks of shale (location 355, elevation 1,690 B.).

The Hagy is only 20 inches thick a mile west of Prater (location 356, elevation 1,565 B.) and also half a mile distant on Greenbrier Creek (location 357, elevation 1,530 B.). It is 23 inches thick on the north side of the creek, northwest of location 357. Northwest of Prater, on a tributary of Greenbrier Creek (location 358, elevation 1,565 B.), the bed is 39 inches thick, including an inch of shale 5 inches from the top, but farther north, at the mouth of Rough Branch, it is only 25 inches thick.

The Hagy is 26 inches thick in a small mine beside the road from Russell Prater to Barts Lick Creek (location 359, elevation 1,473 S.), and is probably about the same elsewhere along the lower part of Russell Prater Creek. It is 25 inches thick near Barts Lick School (location 360, elevation 1,430 B.), but is only 15 to 22 inches thick along lower parts of Barts Lick Creek (location 361, elevation 1,375 B.; location 362, elevation 1,330 B.; location 363, elevation 1,275 B.).

Glamorgan and Lyons coal beds.—The Glamorgan coal is 250 to 340 feet above the Splash Dam coal and only a few feet above the base of the Wise formation. The thickness of coal aggregates a few inches to about $3\frac{1}{2}$ feet, but the bed commonly contains thin shale partings that impair its commercial value. The Lyons bed is 20 to 40 feet above the Glamorgan and is less than 2 feet thick. Neither bed was found along War Fork and the upper part of Russell Prater Creek, and both are probably thin in those districts.

The Glamorgan is about 3 feet thick on the ridge south of lower Russell Prater Creek, and 32 inches of it, the upper part being removed by erosion,

shows in the road east of Prater triangulation station (location 364, elevation 1,916 S.). Here the coal is only 4 inches from the underlying Gladeville sandstone. The Glamorgan is apparently in two thin benches several feet apart in the Greenbrier Creek drainage basin, and near the head of Little Greenbrier Creek (location 365, elevation 1,660 B.) the upper bench contains 30 inches of coal separated into thin layers by intercalations of clay that make the bed valueless.

The character of the Glamorgan along lower Barts Lick Creek is shown by the following four sections, the first one south of the stream and the others north of it:

Sections of Glamorgan coal bed on lower Barts Lick Creek.

(Location 366, elevation 1,450 B.)

	Ft.	in.
Shale.		
Coal	2	
Shale	2	
Coal	4	
Shale	1	
Coal	4	
Shale	1	
Coal	7	
Shale	1	
Coal	1	
Sandstone.		
Coal	2	5
Partings		5

(Location 367, elevation 1,550 B.)

	Ft.	in.
Shale and coal.....	8	
Coal	11	
Shale	1	
Coal	1	
Clay	1	
Coal	1	6
Shale.		
Coal	2	6
Partings		2

(Location 368, elevation 1,510 C. C. C.)

	Ft.	in.
Coal		10
Shale	3	1
Coal		6
"Rash"		2
Coal		6
"Rash"		1
Coal	1	7
Shale.		
Coal	3	5
Partings	3	4

(Location 369, elevation 1,530 B.)

	Ft.	in.
Shale.		
Coal		11
Clay		1
Coal		7
Shale		2
Coal		9
Sandstone.		
Coal	2	3
Partings		3

Blair coal bed.—The Blair is 50 to 120 feet above the Glamorgan coal bed. In many places the bed is in two benches separated by shale several feet thick. One of the benches is so thin as to be of no economic importance, and the other, though containing layers of coal aggregating $1\frac{1}{2}$ to $5\frac{1}{2}$ feet thick, commonly includes several thin layers of incombustible material that make its successful utilization problematical. There are undoubtedly localities, however, in which the bed is sufficiently clean to be an important resource. The Blair is thickest in the Greenbrier Creek drainage basin.

The first of the following sections was measured on a southern tributary of War Fork and the second at the head of War Fork:

Sections of Blair coal bed on War Fork.

(Location 370, elevation 2,105 B.)			(Location 371, elevation 2,170 B.)		
	Ft.	in.		Ft.	in.
Coal		8	Shale		
Shale		1	Coal	1	
Coal		2½	Shale		1½
Shale		1	Coal		4½
Coal		4	Shale		2
Shale		3	Coal	1	4
Coal	1	1	Shale		
Bone		3	Coal	2	8½
Coal		7	Partings		3½
Coal	2	10½			
Partings		8			

At the head of a hollow about half a mile west of Prater (location 372, elevation 1,870 B.), the Blair is about 5 feet thick, including shale partings. The first two of the following sections are on southern tributaries of Greenbrier Creek and the last two are on tributaries of Little Greenbrier Creek. All these measurements are probably of the lower bench, the upper being very thin.

Sections of Blair coal bed on Greenbrier and Little Greenbrier creeks.

(Location 373, elevation 1,810 B.)			(Location 374, elevation 1,850 B.)		
	Ft.	in.		Ft.	in.
Shale			Shale	3	
Coal		8	Coal		9½
Shale		1	Shale		1½
Coal		3	Coal		5
Shale		1	Sandstone		1½
Coal		4	Coal	2	
Shale		2	Shale		
Coal		11	Coal	3	2½
Bone		2	Partings		3
Coal, impure		4			
Bone		1			
Coal	1	8			
Shale		5			
Coal		8			
Coal	4	10			
Partings	1				

(Location 375, elevation 1,750 B.)			(Location 376, elevation 1,720 B.)		
	Ft.	in.		Ft.	in.
Shale			Coal	1	
Coal	1		Bone		8
"Rash"		1	Coal		10
Coal		5			
"Rash"		½	Coal	1	10
Coal	1	4	Parting		8
Coal	2	9			
Partings		1½			

Eagle coal bed.—The Eagle bed lies 140 to 200 feet above the Glamorgan coal and a few feet below a thick sandstone that makes conspicuous cliffs. In places this bed is only 20 feet above the Blair, but in others the interval is 50 to 100 feet. The coal is not very thick north of Barts Lick Creek and in part of the Greenbrier Creek drainage basin, but elsewhere in this area it is fairly clean and has an average thickness of 4 or 4½ feet. Near the heads of Russell Prater Creek and War Fork it is about 5 feet thick. The bed lies so high in the hills that it has a comparatively small acreage. One of the peculiarities of the Eagle in places is a very thin sandstone parting much like the one that is characteristic of the Upper Banner bed farther south.

The Eagle is naturally exposed on a slope near Prater triangulation station, south of Russell Prater Creek (location 377, elevation 2,040 B.) and is 68 inches thick, including 3 inches of shale a foot below the top. At the head of War Fork (location 378, elevation 2,215 B.) the bed is 65 inches thick and remarkably clean. The roof is 10 feet of shale under sandstone and there is a 12-inch coal bed 75 feet above the Eagle. The Eagle is nearly as thick 2½ miles northwest, in the bottom of a hollow near the head of Russell Prater Creek (location 379, elevation 2,070 B.), where there are 58 inches of coal in addition to a 9-inch shale parting 32 inches from the top. Sandstone 25 feet thick may be seen resting on the coal, and the total thickness of this cap is probably about 100 feet. The bed appears to be 4 or 5 feet thick at an abandoned strip pit a mile north of this, at the head of Camp Branch of Poplar Creek (location 380, elevation 1,970 B.).

There are no indications of very thick coal at the Eagle horizon along Greenbrier Creek above the mouth of Little Greenbrier, though there may be some near the head of the stream. The bed is 32 inches thick, including an inch of shale, in the first hollow to the right above Little Greenbrier Creek (location 381, elevation 1,830 B.). The four measurements given below show thicker coal on tributaries of Little Greenbrier Creek:

Sections of Eagle coal bed on Little Greenbrier Creek.

(Location 382, elevation 1,850 B.)

	Ft.	in.
Coal	1	1
Shale		3
Coal	1	2
Shale		3
Coal	1	2
Shale		4
Coal	3	
Coal	6	5
Partings		10

(Location 383, elevation 1,800 B.)

	Ft.	in.
Coal	?	?
Shale	1	8
Coal		8
Shale		½
Coal		4
Sandstone		1
Coal	2	1
Coal	3	1
Partings		1½

(Location 384, elevation 1,810 B.)

	Ft.	in.
Shale	1	
Coal		1½
Clay		¾
Coal	3	1
Clay		½
Coal		5½
Sandstone		¼
Coal	1	7
Clay.		
Coal	5	3
Partings		1½

(Location 385, elevation 1,820 B.)

	Ft.	in.
Shale.		
Coal		1
Clay		1
Coal		11½
Clay		½
Coal	1	3
"Rash"		2
Coal	2	9½
Coal	5	1
Partings		3½

The following measurements were made at two small mines that have supplied fuel for lumbering operations, the first being on Wolfpen Branch of Russell Prater Creek, east of Greenbrier Creek, and the second on Slate Branch of Barts Lick Creek:

Sections of Eagle coal bed on Wolfpen and Slate branches.

(Location 386, elevation 1,925 C. C. C.)

	Ft.	in.
Shale	11	
Coal		1
Clay		¼
Coal	3	5
Clay		1
Coal	1	
Shale.		
Coal	4	6
Partings		1¼

(Location 387, elevation 1,827 C. C. C.)

	Ft.	in.
Sandstone.		
Coal		9½
Clay		5½
Coal	1	1
Clay		1
Coal	1	11½
Sandstone		1½
Coal	1	2
Coal	4	2
Partings		8

Levisa Fork drainage basin.

LEVISA FORK AND TRIBUTARIES OTHER THAN PRATER AND GARDEN CREEKS.

Geologic outline.—This area, which embraces the valley of Levisa Fork, the drainage basins of Little Prater and Dismal creeks, and a number of small tributaries of the Levisa, contains exposures of rocks from the sandstone bottom rock of the Tiller coal bed to beds about 450 feet above the base of the Wise formation. The stratigraphy is shown by a generalized columnar section for the north third of the Bucu quadrangle (Pl. IV) and by local sections 18, 21, 22, and 23. Dips are to the northwest, west, and north and are very gentle in most places.

The most important beds commercially are the Lower Banner (Cary) east of Dismal Creek, the Kennedy (Harris), and the Eagle. (See figs.

3, 4, 5, and 17.) The lowest coal bed exposed is the Tiller (Garden), which is 30 inches or less thick. Both the Jawbone, Ratliff, and Garden Hole beds are less than 30 inches thick. The Kennedy is a persistent bed which is about 3 to 4 feet thick east of Prater and Dismal creeks and thins gradually to the north and west. The Lower Banner is a thin bed 4 to 5½ feet thick southeast of Dismal Creek, but much thinner farther west. The Upper Banner is probably not present and the Splash, Dam and Hagy, as far as now known, are less than 30 inches thick except near the head of Little Prater Creek, where they are nearly 3 feet thick. Several beds in

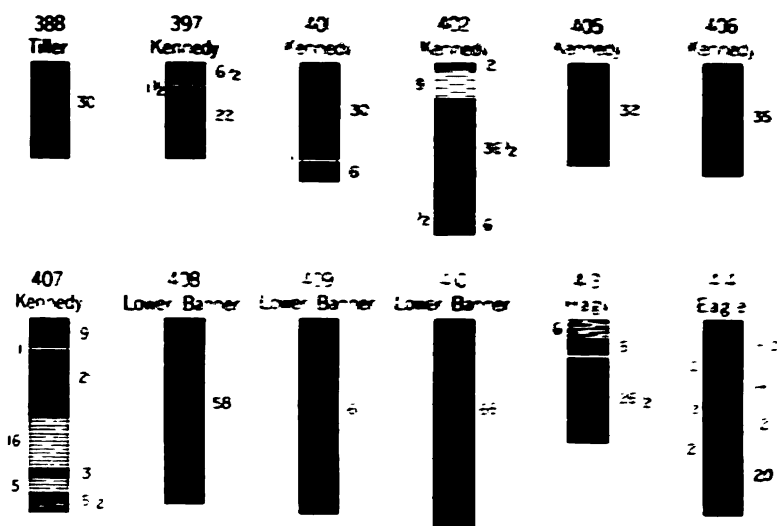


Fig. 17.—Sections of coal beds on and near Lewis Fork.

the Wise formation, found only on the ridges near Little Prater Creek, may be moderately thick, and the Eagle is known to be about 5 feet thick in the small area it underlies.

Tiller coal bed.—The Tiller is the lowest coal bed exposed in the area and outcrops a short distance above Lewis Fork east of a point a mile northeast of Van Sant. It is called the Garden bed in a private report by d'Invilliers. The bed lies above a coarse-grained, massive conglomeratic sandstone and is 690 to 750 feet below the Splash Dam horizon. Above the Tiller there are commonly 20 to 50 feet of blue and drab shale underlying a large 50-foot lentil of siliceous conglomeratic sandstone. The coal is 27 to 30 inches thick near Dismal and Garden creeks and thinner farther west.

There is a small mine in the bank of the Levisa opposite the mouth of Garden Creek (location 388, elevation 1,320 H. L.), in which the Tiller coal is 30 inches thick and has a sandstone roof and shale floor. A mile northwest of this, beside the road (location 389, elevation 1,329 S.), and at the mouth of Dismal Creek (location 390, elevation 1,170 B.), the coal is 27 inches thick. Near river level a mile northeast of Van Sant (location 391, elevation 1,110 B.), the bed is only 19 inches thick, including a 4-inch shale layer in the middle.

Jawbone coal bed.—The Jawbone is less than 2 feet thick and is 50 to 100 feet above the Tiller, lying on the conglomeratic lentil previously mentioned. This bed is locally known as the Ratliff. The coal is 20 inches thick at the mouth of Dismal Creek and 22 inches thick $1\frac{1}{4}$ miles northeast (location 392, elevation 1,232 S.). At the mouth of Prater Creek (location 393, elevation 1,125 B.) the coal is 20 to 24 inches thick and has 10 feet of drab shale in the roof.

Garden Hole coal bed.—The Garden Hole bed is 460 to 525 feet below the Splash Dam horizon and about 200 feet above the Tiller. Under it there is an arkosic sandstone that makes more or less prominent cliffs in places. The bed was measured at only two pits, but is probably less than 30 inches thick elsewhere. At a small mine opposite Little Prater School (location 394, elevation 1,155 B.), the bed is 26 inches thick and has a roof of dark drab shale 8 feet thick. An opening near the mouth of Prater Creek (location 395, elevation 1,200 B.) is in coal 28 to 30 inches thick. The bed is reported 27 inches thick at the mouth of Prater Creek and 21 inches on Mill Branch of Dismal Creek.

Kennedy coal bed.—The Kennedy bed, locally known as the Harris, lies on a thick massive sandstone that makes conspicuous ledges and cliffs, and is 300 to 350 feet below the Splash Dam horizon, in most places a little less than 200 feet above the Garden Hole bed. The roof is sandy shale in most localities. The bed has few partings and contains coal 32 to 45 inches thick east of Prater and Dismal creeks. In general the bed thins gradually to the north and west, and is only about 27 inches thick along Little Prater Creek.

Four small mines on Little Prater Creek (locations 396, 397, 398, and 399, elevations 1,320 to 1,330) utilize the Kennedy bed, which is 27 to 30 inches thick, including one-quarter to $1\frac{1}{2}$ inches of shale 6 inches from the top. The roof is sandy shale at least 25 feet thick.

A little more than a mile east of Van Sant (location 400, elevation 1,600 B.) and at a small mine on Sixteen Mile Branch (location 401,

elevation 1,645 B.) the coal is about 3 feet thick, with an inch of shale in the lower part. D'Inwilliers gives the following measurements on Kennel Branch, at the east edge of the Bucu quadrangle:

Section of Kennedy coal bed on Kennel Branch.

(Location 402, elevation 1,680 B.)

	Ft.	in.
Coal		2
Sandstone and shale.....		9
Coal	3	$\frac{1}{2}$
Clay		$\frac{1}{2}$
Coal		6
Coal	3	$8\frac{1}{2}$
Partings		$9\frac{1}{2}$

The same authority gives the thickness of the bed as 3 feet on Pigeon Branch, 32 inches near the mouth of Dismal Creek, and $37\frac{1}{2}$ inches on Mill Branch of Dismal Creek, including shale $11\frac{1}{2}$ inches thick at the last opening. Harnsberger, however, found the thickness to be only 28 inches in a small mine on Mill Branch a few rods east of the quadrangle, possibly because the lower part of the bed was not utilized. On the south side of Harper Creek of Dismal Creek (location 403, elevation 1,560 B.), the coal is $27\frac{1}{2}$ inches thick and has a roof of shaly sandstone. It is the same thickness on Stilton Branch of Levisa Fork (location 404, elevation 1,570 B.), but has there a shale roof. West of this there is a local thickening of the coal, which is 32 inches thick on Bens Branch (location 405, elevation 1,470 B.), 35 inches a short distance southwest (location 406, elevation 1,430 B.), and is as follows at a small mine half a mile farther west:

Section of Kennedy coal bed north of Van Sant.

(Location 407, elevation 1,360 B.)

	Ft.	in.
Shale	6	
Coal		9
Shale		1
Coal	1	9
Shale	1	4
Coal		3
Shale		5
Coal, impure		$5\frac{1}{2}$
Shale, compact.....		
Coal	3	$2\frac{1}{2}$
Partings	1	10

Lower Banner coal bed.—The Lower Banner, locally called the Cary, is 130 to 200 feet above the Kennedy coal and 140 to 200 feet below the Splash Dam horizon, the intervals decreasing from east to west. A few feet below the coal there is a sandstone bed that makes rather inconspicuous ledges, and the roof is commonly shale. The Lower Banner is remarkably clean and contains coal 4 to $5\frac{1}{2}$ feet thick in most of the district between Dismal Creek and Levisa Fork and south of the Levisa near Garden Creek. West of this district the coal thins and becomes unworkable within a short distance.

The Lower Banner coal is reported 50 inches thick just west of the mouth of Garden Creek and is 54 inches on Kennel Branch, a short distance east of the Bucu quadrangle. On Pigeon Branch (location 408, elevation 1,880 B.), the coal is 58 inches thick and it is 61 inches thick less than a mile northwest (location 409, elevation 1,900 B.). West of the last pit the bed thins and is reported by d'Inwilliers to be only 2 feet thick at the mouth of Dismal Creek. On Mill Branch, however, the bed is in good condition and is $5\frac{1}{2}$ feet thick at the east edge of the quadrangle (location 410, elevation 1,875 B.). There are reported to be 34 inches of coal on the north side of Dismal Creek near the northeast corner of the quadrangle, but the bed thins to the southwest and is only 10 inches thick on Stilton Branch of Levisa.

Splash Dam coal bed.—The Splash Dam coal lies a few feet above a thick sandstone bed that makes conspicuous cliffs on narrow spurs. The horizon of the bed can be easily identified but the coal itself was found in only a few places. The coal is known to be thick a short distance north of Little Prater Creek and was reported to be 26 to 51 inches thick on that stream. It is thinner farther east and south, perhaps because it is split into two parts by a shale bed, though it is possible that it is about 3 feet thick along the east edge of the Bucu quadrangle.

The Splash Dam bed is 26 inches thick and has a shale roof containing fossil plants on a southern tributary of Little Prater Creek (location 411, elevation 1,650 B.). On Little Prater Creek, three-quarters of a mile southwest of this opening, the bed is reported to be 3 feet thick, and at the head of a southern tributary which enters Little Prater near its mouth, half a mile east of location 411, the bed is reported 54 inches thick, including 3 inches of shale. These reports, however, need confirmation. The reported thickness is 27 inches at the head of Sixteen Mile Branch of Levisa Fork and 21 inches at the head of Bens Branch (location 412, elevation 1,790 B.).

Hagy coal bed.—The Hagy is 60 to 100 feet above the Splash Dam horizon. This bed is about $2\frac{1}{2}$ feet thick near the head of Little Prater Creek, where the measurement given below was made, but is thought to be only 2 feet or less thick elsewhere in this area. In place there is another thin coal bed a short distance above the Hagy.

Section of Hagy coal bed at head of Little Prater Creek.

(Location 413, elevation 1,773 H. L.)

	Ft.	in.
Shale, dark	4	
Coal and shale, interbedded.....		6
Coal		5
Shale		1
Coal	2	$2\frac{1}{2}$
Interval to sandstone ledge.....	8	
Coal	2	$7\frac{1}{2}$
Partings		1

Coal beds in Wise formation.—Coal beds in the Wise are confined, in this area, to the tops of the ridges on both sides of Little Prater Creek. As indicated by exposures in neighboring areas, described in the sections devoted to the Russell Prater and Prater Creek drainage basins, there is probably some coal at the Glamorgan, Blair, and Clintwood horizons. The only measurement obtained in this area, however, was of the Eagle bed near the head of Little Prater Creek, and is given below. The Eagle is 170 feet above the base of the Wise formation and about 460 feet above the Splash Dam horizon. It underlies a light-colored, coarse sandstone that forms strong cliffs and is 50 feet or more thick.

Section of Eagle coal bed near head of Little Prater Creek.

(Location 414, elevation 2,100 B.)

	Ft.	in.
Sandstone, shaly, under coarse, massive sandstone cliff....	2	
Coal, with two or three shale streaks.....	1	$\frac{1}{2}$
Shale		$\frac{1}{2}$
Coal	1	2
Shale		$\frac{1}{2}$
Coal, with two shale streaks.....	1	
Shale, carbonaceous		2
Coal	1	8
Coal	4	$10\frac{1}{2}$
Partings		3

PRATER CREEK.

Geologic outline.—Rocks from a few feet below the Jawbone coal horizon to about 450 feet above the base of the Wise formation are exposed in the Prater Creek drainage basin, but the Wise and Gladeville formations occur only on the tops of a few ridges. The stratigraphy of the exposed rocks is shown graphically by the generalized columnar sections for the middle and north thirds of the Bucu quadrangle (Pl. IV), and by the local sections 24, 25, 26, and 27. There are a few small anticlines and synclines which cause local irregularities, but in general dips are very gentle and are to the

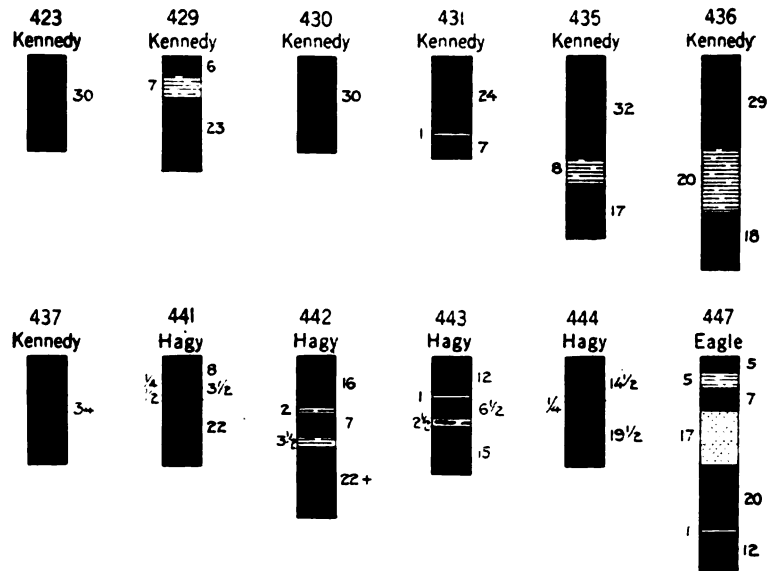


Fig. 18.—Sections of coal beds in the Prater Creek drainage basin.

north or northwest. Dips are slightly greater in the central part of the area than elsewhere.

The Kennedy and Hagy coal beds are commercially the most important in the area, though there are workable beds at other horizons. The Eagle coal is the thickest, but underlies only small areas on high ridges west of Prater Creek. (See figs. 3, 5, and 18.)

The Jawbone and Garden Hole beds and a coal 75 feet above the latter are less than 2 feet thick nearly everywhere in this area. The Kennedy

coal, excluding partings, is about 4 feet thick along the upper part of Dry Fork and thins to the west and northwest to a thickness of 20 or 30 inches. The Upper Banner is probably absent except along part of Trace Fork, and the Splash Dam bed is thin. The Hagy bed is about 3 feet thick in the southwestern part of the area and thinner elsewhere. The Glamorgan bed is less than 30 inches thick and the Blair probably more than 30 inches locally. The Eagle coal is $3\frac{1}{2}$ to about 5 feet thick, exclusive of partings.

Jawbone coal bed.—The Jawbone coal, which is about 620 feet below the Splash Dam, is above drainage levels only along the lower part of Prater Creek and is a thin bed of little economic importance in this district. It is 17 inches thick in the bed of Prater Creek near the mouth of Trace Fork (location 415, elevation 1,171 S.) and 15 inches a few rods down the stream. The coal is 21 to 27 inches thick near the mouth of Dry Fork (location 416, elevation 1,145 B.).

Garden Hole and associated coal beds.—The Garden Hole bed lies about 90 feet above the Jawbone and 520 to 570 feet below the Splash Dam horizon. It outcrops low down in the valley of Prater Creek from its mouth nearly to its head and along the lower parts of the principal tributaries. The thickness of the bed is only about 2 feet. There is a 21-inch coal bed about 75 feet above the Garden Hole near the head of Prater Creek.

The Garden Hole bed is 25 inches thick at the mouth of Big Lick Branch (location 417, elevation 1,255 H. L.) and 19 inches at a neighboring exposure on Trace Fork.

The coal bed 75 feet above the Garden Hole is 23 inches thick on Whitt Branch of Prater Creek (location 418, elevation 1,670 S.), and 21 inches thick by the road up Crooked Branch (location 419, elevation 1,717 S.) and in a pit half a mile southwest. The Garden Hole bed is about 2 feet thick in this locality, but is only 15 to 20 inches thick on Box Camp Branch (location 420, elevation 1,620 B.). An opening on Murphy Fork (location 421, elevation 1,600 B.) shows the Garden Hole to be 24 to 28 inches thick and it is about the same at Deskins and on Three Forks Branch (location 422, elevation 1,585 B.).

Kennedy coal bed.—The Kennedy is 200 feet and more above the Garden Hole bed and 300 to 350 feet below the Splash Dam horizon, the intervals decreasing from southeast to northwest. Coal is very persistent at the Kennedy horizon, and is 20 to 30 inches thick along Trace Fork, 2 to 3 feet along Prater Creek and its small tributaries, and about 4 feet along the upper part of Dry Fork. In general, therefore, the bed thins to the

west. Where the coal is thickest, the bed commonly includes a shale parting. The roof is drab shale, sandy in places, and a coarse, cliff-making sandstone lies a few feet below the coal.

The Kennedy is 30 inches thick in a small mine on the West side of Prater Creek, near its mouth (location 423, elevation 1,445 B.). About a mile southwest of the mouth of Trace Fork (location 424, elevation 1,465 B.), the coal is 21 inches thick and is only $19\frac{1}{2}$ inches a mile farther southwest (location 425, elevation 1,439 S.). A small family mine on Mott Branch of Trace Fork (location 426, elevation 1,485 B.) shows the Kennedy to be only $22\frac{1}{2}$ inches thick, but it is said to be 30 inches in the neighborhood. At the mouth of Trace Fork (location 427, elevation 1,480 B.), the bed is 27 inches thick.

The Kennedy is 29 inches thick opposite the mouth of Devil Branch of Prater Creek (location 428, elevation 1,490 B.). A small mine near a house on Shortridge Branch (location 429, elevation 1,620 B.) and two prospect pits in the vicinity show a carbonaceous shale parting 3 to 12 inches thick, the coal above it being 6 to 8 inches thick and that below it 20 to 26 inches thick. On Whitt Branch, half a mile west of its mouth (location 430, elevation 1,795 B.), the bed is clean and 28 to 32 inches thick. On a northern tributary of Crooked Branch (location 431, elevation 1,850 B.) the bed is 32 inches thick, including an inch of shale, and it is said to be thicker on a southern tributary, near Indian Grave Gap (location 432, elevation 1,855 H. L.). The Kennedy is reported 30 to 32 inches thick on the upper part of Three Forks Branch (location 433, elevation 1,775 B.) and is 29 inches on Vance Branch (location 434, elevation 1,675 B.).

The bed is thickest on the upper part of Dry Fork, as shown by the following measurements in small mines:

Sections of Kennedy coal bed on Dry Fork of Prater Creek.

(Location 435, elevation 1,675 B.)			(Location 436, elevation 1,717 S.)		
	Ft.	in.		Ft.	in.
Coal	2	8	Coal	2	5
Shale		8	Shale	1	8
Coal	1	5	Coal	1	6
Coal	4	1	Coal	3	11
Parting		8	Parting	1	8

The bed is 27 inches thick and without the shale parting near the mouth of Dry Fork, and is 34 inches thick in a small mine 300 yards northwest (location 437, elevation 1,475 B.).

Lower and Upper Banner and Splash Dam coal beds.—The Lower Banner bed was not found in this area and is probably thin. The Upper Banner bed was found at only one place, shown in the section given below, and its thickness there is surprising. The Upper Banner is thin or absent in most other parts of the Levisa Fork drainage basin and neighboring parts of the Russell Fork drainage basin.

Section in bed of tributary of Mott Branch of Trace Fork.

(Location 438.)

	Ft.	in.
Shale	10	
Coal (Hagy, elevation 1,920), in caved pit.....		
Concealed	10	
Sandstone, massive at top, thin-bedded at base.....	86	
Shale, buff, sandy	4	
Coal (Splash Dam, elevation 1,820), with bony streaks...	1½	
Concealed	10	
Sandstone, medium-grained, firmly cemented.....	35	
Coal (Upper Banner, elevation 1,775), reported 4 feet thick, now exposed	2½	
	159	

The only other measurement of the Splash Dam bed was made near the head of Big Lick Branch (location 439, elevation 1,730 S.), where the coal is 21 inches thick. The bed is probably less than 2 feet thick in most of the Prater Creek drainage basin.

Hagy coal bed.—The Hagy bed is 80 to 120 feet above the Splash Dam horizon, a few feet above a sandstone that makes fairly strong ledges, and a few feet below a thinner and less conspicuous sandstone. Drab shale commonly lies directly on the coal. The thickness of the coal is exceptionally great on the west side of the southern part of the Trace Fork drainage basin, averaging nearly 3 feet and being about 4 feet at one pit. Elsewhere the bed is probably less than 2 feet thick. Run of mine coal from this district would be high in ash because of thin streaks of shale and bone.

The Hagy is 33 inches thick near the head of Big Lick Branch (location 440, elevation 1,850 B.), but the upper 13 inches is a worthless mixture of interbedded shale and coal and there is an inch of shale 16 inches from the base of the bed. The upper part of the bed improves in quality to the south and includes only a few streaks of shale in the gap between Trace Fork and Pawpaw Creek, where the first of the following sections was measured. The second of these sections is from a pit nearly a mile south of the first and is not complete, as the bottom of the bed was not seen. The

third and fourth sections were obtained a short distance south of the second, the fourth being from a small mine at a sharp bend in the wagon road from Fox Creek, on land of H. E. Hagy.

Sections of Hagy coal bed near head of Trace Fork.

(Location 441, elevation 1,871 S.)

	Ft.	in.
Shale	6	
Coal		8
Shale		$\frac{1}{4}$
Coal		$3\frac{1}{2}$
Shale		$\frac{1}{2}$
Coal	1	10
Coal	2	$9\frac{1}{2}$
Partings		$\frac{3}{4}$

(Location 442, elevation 1,890 B.)

	Ft.	in.
Shale	8	
Coal	1	4
Shale		2
Coal		7
Shale		$3\frac{1}{2}$
Coal	1	10+
Coal	3	4+
Partings		$5\frac{1}{2}$

(Location 443, elevation 1,895 B.)

	Ft.	in.
Shale		
Coal	1	
Bone		1
Coal		$6\frac{1}{2}$
Bone		$2\frac{1}{2}$
Coal	1	3
Coal	2	$9\frac{1}{2}$
Partings		$3\frac{1}{2}$

(Location 444, elevation 1,911 S.)

	Ft.	in.
Shale	15	
Coal	1	$2\frac{1}{2}$
Bone		$\frac{1}{4}$
Coal	1	$7\frac{1}{2}$
Coal	2	10
Parting		$\frac{1}{4}$

The Hagy is reported to be 30 inches thick in a hollow northeast of Leemaster (location 445, elevation 1,895 B.).

Coal beds in Wise formation.—There are known to be three coal beds in the lower part of the Wise formation, but they underlie only small areas on the tops of some of the high ridges. The Glamorgan bed, which is at the base of the formation, is probably thin in most places. It is 29 inches thick, including two 1-inch shale partings, at the head of Big Rock Branch, where it is 300 feet above the Splash Dam horizon. About 200 yards up the same hollow (location 446, elevation 2,130 B.), a bed that is either the Eagle or the Blair has been opened at a level 140 feet above that of the Glamorgan. The coal is reported to be only 29 inches thick here, but this probably includes only the lower part of the bed. The following is a more complete section from an opening 800 feet southeast.

Section of Eagle (?) coal bed at head of Big Rock Branch.

(Location 447, elevation 2,130 B.)

	Ft.	in.
Coal		5
Shale		5
Coal		7
Sandstone	1	5
Coal	1	8
Shale		1
Coal	1	
Coal	3	8
Partings	1	11

The thickness of the Eagle bed farther west is indicated by that in an opening already described on Little Prater Creek (location 414). An exposure of the Eagle in a southern tributary of Big Lick Branch (location 448, elevation 2,190 B.) shows 39 inches of coal, and more is said to be separated from it by a shale parting. There is a thin coal bed a short distance above the Eagle and another, probably the Blair, a short distance below. The excellent character of the Eagle and Blair beds farther south on this ridge is shown at pits in the Russell Prater Creek (locations 371 and 378) and Pawpaw Creek (location 340) drainage basins, described on preceding pages.

The Clintwood coal may be present at the top of some of the high knobs on the west side of the area, but it has not been found by prospectors.

GARDEN CREEK.

Geologic outline.—Rocks exposed in that part of the Garden Creek drainage basin which lies within the Bucu quadrangle include the Norton formation above the Tiller coal, the Gladeville sandstone, and a few feet of rocks at the base of the Wise formation. The Gladeville, however, occurs only on the tops of a few ridges and the Wise only in small patches on the tops of a few knobs. The succession of strata is shown by the generalized columnar sections (Pl. IV) for the north and middle thirds of the Bucu quadrangle and by local sections 21, 27, and 28. Structurally the area is dominated by a general dip to the northwest and north, much steeper on the south than on the north.

The Tiller, Jawbone, Garden Hole, and the next higher coal bed are 30 inches or less thick where they reach the surface, though the first two may thicken under cover to the south. The Kennedy coal is 3 to nearly 5 feet thick in the northeastern part of the area and $2\frac{1}{2}$ to 3 feet elsewhere.

The Lower Banner bed is about 4 feet thick on the eastern border of the area and thins to the west. The Upper Banner is thin and the Splash Dam is fairly thick in places and probably thin in others. (See figs. 3, 4, and 19.)

Tiller and Jawbone coal beds.—The Tiller bed, locally called the Garden, is exposed only in the stream bank near the mouth of Garden Creek (location 449, elevation 1,330 B.), where it is 30 inches thick and 715 feet below the Splash Dam horizon. The Jawbone bed, locally called the Ratliff, was not found, but is probably thin and about 60 feet above the Tiller. Both beds may be thicker under the southern part of the area.

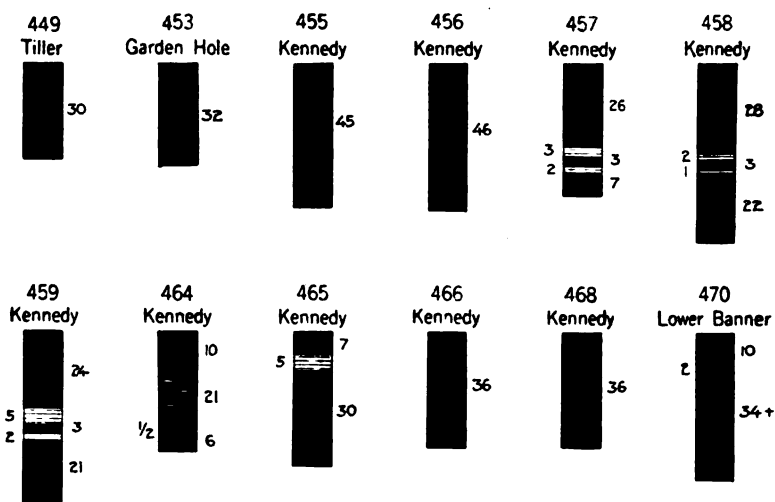


Fig. 19.—Sections of coal beds in the Garden Creek drainage basin.

Garden Hole and associated coal beds.—The Garden Hole coal is 560 to 610 feet below the Splash Dam horizon and is 15 to 30 inches thick. In the southern part of the area there is another bed of about the same thickness 50 to 100 feet above the Garden Hole.

The Garden Hole coal is 20 inches thick near a house on Little Garden Creek (location 450, elevation 1,510 B.), with medium-grained sandstone for a roof. The coal is reported to be 30 inches thick half a mile south of the mouth of Little Garden. The bed above the Garden Hole is 20 inches thick at stream level on Robinson Fork of Right Fork (location 451, elevation 1,735 B.), and is slightly thicker in the road near the mouth of the stream. The Garden Hole bed is 26 inches thick on the right fork of Long

Fork (location 452, elevation 1,820 B.) and 27 to 32 inches thick in two neighboring pits on the left fork (location 453, elevation 1,865 B.). A pit in a small hollow in the upper part of Whitt Fork (location 454, elevation 2,030 B.) shows coal 25 inches thick at the Garden Hole horizon, but there are only 18 inches in a pit under the wagon road a short distance east.

Kennedy coal bed.—The Kennedy coal, locally called the Harris, is a persistent and valuable bed in this area and lies 300 to 360 feet below the Splash Dam horizon. The position of the coal is marked by a massive coarse-grained, ledge-making sandstone a few feet below it. The roof of the coal is commonly drab shale, in places so sandy as to be almost a sandstone. The Kennedy, exclusive of partings, is nearly 4 feet thick along the lower part of Garden Creek, and is 3 to nearly 5 feet thick on both sides of the lower part of Right Fork. Elsewhere in this drainage basin it is about 2½ to 3 feet thick. In some localities the bed is nearly all coal, in others there are several shale partings of irregular thickness.

In a hollow half a mile south of the mouth of Little Garden Creek (location 455, elevation 1,715 B.), the Kennedy is 45 inches thick, possibly including an inch or two of shale. In another hollow three-quarters of a mile farther south (location 456, elevation 1,730 B.) the bed is 46 inches thick.

There are several prospect pits and small mines on the north side of Youngs Branch, two of the sections obtained being shown below. The thickness of coal and partings is not the same in all parts of the mine in which the second section was measured and as much as 59 inches of coal was seen at one place in it.

Sections of Kennedy coal bed on Youngs Branch.

(Location 457, elevation 1,764 S.)			(Location 458, elevation 1,740 B.)		
	Ft.	in.		Ft.	in.
Shale	2		Shale		
Coal	2	2	Coal	2	4
Shale		3	Shale		2
Coal		3	Coal		3
Shale		2	Shale		1
Coal		7	Coal	1	10
Coal	3		Coal	4	5
Partings		5	Partings		3

The bed is about the same on the upper part of Skeggs Branch, as shown by the following section, the lower part of which was reported by Catlett:

Section of Kennedy coal bed on Skeggs Branch.

(Location 459, elevation 1,780 B.)

	Ft.	in.
Shale, dark blue at base.....	20	
Coal	2	
Shale		5
Coal		3
Shale		2
Coal	1	9
Interval to top of massive sandstone, about.....	2	6
Coal	4	
Partings		7

Residents report that there is clean coal 42 inches thick in a caved pit near the mouth of Skeggs Branch (location 460, elevation 1,775 B.). The Kennedy is without partings on Breeden Branch and is reported by Catlett to be 3 feet thick in a pit near the head of the valley (location 461, elevation 1,783 H. L.). Farther south it is 28 inches thick in one pit (location 462, elevation 1,790 B.) and 29 inches in another (location 463, elevation 1,840 B.). The coal is 37 inches thick near the head of Robinson Fork (location 464, elevation 1,820 B.), but is slightly crushed and dirty in the middle.

The Kennedy includes 37 inches of coal on Long Fork (location 465, elevation 2,075 B.), in addition to a 5-inch black shale parting 7 inches from the top. A small mine farther east, on a southern tributary of Whitt Fork (location 466, elevation 2,150 B.), is in clean coal 36 inches thick. A small mine near the road at the head of Whitt Fork (location 467, elevation 2,305 B.) shows 26 inches of coal, crushed and slickensided, underlain by 6 inches of intermingled clay and coal resting on very hard sandy shale.

The Kennedy was found at only two places on the southeast side of Right Fork, at one of which (location 468, elevation 1,900) coal 36 inches thick is separated from sandstone below by only 2 inches of carbonaceous shale. Dilworth states that the coal is 43 inches thick near the mouth of North Branch, and a resident claims that the bed is a little more than 3 feet thick near one of the heads of that stream (location 469, elevation 1,920 B.).

Lower Banner coal bed.—The Lower Banner coal, locally called the Cary, is 130 to 200 feet below the Splash Dam horizon and 130 to 200 feet above the Kennedy. It is a nearly clean coal bed about 4 feet thick along the eastern border of the Bucu quadrangle in this area, but thins to the

west. More thorough prospecting is necessary before the limits of workable coal can be exactly determined.

The Lower Banner coal is reported to be 50 inches thick on the hillside west of the mouth of Garden Creek. It was not found on the tributaries of Right Fork except at the head of Rosin Camp Branch (location 470, elevation 2,440 B.), where it is more than 46 inches thick, including a 2-inch parting of carbonaceous shale 10 inches from the top. On the west side of the left or principal fork of Garden Creek, on the east boundary of the quadrangle (location 471, elevation 1,985 B.), the thickness of coal is at least 47 inches, and may be slightly more.

Upper Banner and Splash Dam coal beds.—The Upper Banner bed, 50 to 100 feet below the Splash Dam, is probably thin in all this area. The only place at which it was found to be more than a few inches thick is on the side of Fletcher Ridge (location 472, elevation 2,310 B.), where 20 inches were seen. Very little is known about the Splash Dam bed, which is probably the same as the Wilson of the upper Levisa Fork region. It is probably an important bed in places, but it seems likely that it would have been more extensively prospected if it were thick in many localities. Several inhabitants said that it was 4 feet thick in a pit west of Breeden Branch (location 473, elevation 2,190 B.). As previously stated, a bloom indicating coal at least 3 feet thick shows at the Splash Dam horizon on Fletcher Ridge (location 328).

Clinch River drainage basin.

LEWIS CREEK.

Geologic outline.—Only a small area on the western side of Lewis Creek drainage basin is in the Bucu quadrangle, and it contains rocks from a few feet below the Aily coal horizon nearly to the top of the Norton formation. The stratigraphic succession is indicated by the generalized columnar sections for the north and middle thirds of the Bucu quadrangle (Pl. IV) and by local section 28.

The axis of the Dry Fork anticline passes from east to west through the northern part of the area and beds near it have almost no dip. In the southern part of the area the dip is to the south and east and is irregular near the great fault which limits this part of the coal field on the southwest. Southwest of this fault the only beds exposed are the pre-Pennsylvanian formations that have been thrust up over the coal-bearing strata.

The most important coal bed is the Kennedy, which is utilized at small shipping mines near Drill. It is very irregular in thickness, ranging from 18 to 77 inches but probably averaging 3 feet. The average thickness of the Lower Banner is also about 3 feet, exclusive of partings. (See figs. 3, 4, and 20.) The Upper Banner, Splash Dam, and Hagy beds contain an unknown amount of coal, but are not thought to be very thick in this area.

Aily coal bed.—A bed that is tentatively correlated with the Aily, which is about 450 feet below the Splash Dam horizon in this area, is mined for a moderately large local trade by W. N. Jackson on Laurel Branch, at the east boundary of the quadrangle (location 474, elevation 2,030 B.). The stratigraphic position of this bed is rendered uncertain by the irregular dips in the vicinity and by the proximity of a great fault. Dips measured in the mine range from 5 to 18 degrees to the northeast and north and thicknesses

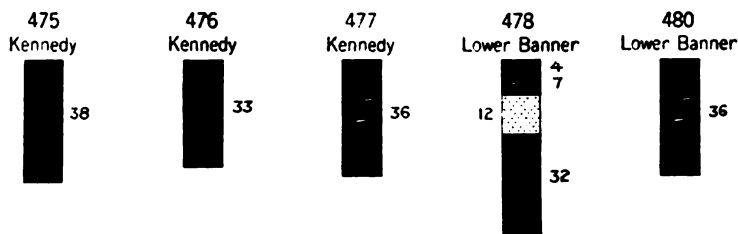


Fig. 20.—Sections of coal beds in the Lewis Creek drainage basin.

of coal from $2\frac{1}{2}$ to 11 feet, the average being about 4 feet. Both the floor and roof are hard clay that gives little trouble. An analysis of a sample from this mine is given in another part of this report. What is probably the same bed has been mined 1,300 feet south of Jackson drift.

Kennedy coal bed.—The Kennedy coal, which is a few feet above coarse-grained, ledge-making sandstone, is about 350 feet below the Splash Dam horizon. It is irregular in thickness, ranging from 18 to as much as 77 inches where found, but averages about 3 feet. It has a shale roof in most places.

A small drift by the wagon road nearly a mile north of Drill, outside the Bucu quadrangle, shows the Kennedy to be 77 inches thick at the mouth and only 54 inches at the face, the irregularity of thickness being due to the uneven roof and to slight movement along the bedding planes of the coal. The same bed is mined in a drift at Drill (location 475, elevation 2,316 S.) to supply the engines on the Honaker Lumber Company railroad,

about ten men being employed in 1914. The thickness of the bed in the mine ranges from 18 to 43 inches. An analysis of a mine sample is given elsewhere in this report. The coal is 33 inches thick a short distance northwest of Drill (location 476, elevation 2,315 B.).

The Sandy Ridge Coal & Coke Company has recently begun operations half a mile south of Drill, and has driven two drifts, one on the north side of a small spur (location 477, elevation 2,334 H. L.) and the other on the south side. Small shipments were being made over the Honaker Lumber Company's railroad when the mine was visited in 1914 and 1915. The thickness of coal is 30 to 62 inches in the mine, averaging about 3 feet. The roof is shale and the floor a hard clay with rolls that cause many of the inequalities in the coal thicknesses.

Lower Banner coal bed.—The Lower Banner bed is about 160 feet below the Splash Dam horizon and is 22 to more than 36 inches thick at the few places it could be measured. The roof is commonly drab shale. The following section was made in a small mine in the head of a hollow near Drill.

Section of Lower Banner coal bed three-quarters of a mile northwest of Drill.

(Location 478, elevation 2,520 B.)

	Ft.	in.
Sandstone, medium-grained	10	
Coal, dirty except at top		11
Sandstone, fine-grained	1	
Coal	2	8
Coal	3	7
Parting	1	

A coal bed that lies 60 or 70 feet above the Lower Banner is 29 inches thick at the side of the railroad gap a short distance southwest of location 478, but this thickness includes that of an 8-inch sandstone parting near the base. Slightly more than a mile south of Drill (location 479, elevation 2,430 B.) the Lower Banner coal is 22 inches thick. A pit on the west side of Grassy Creek (location 480, elevation 2,460 B.) shows the same bed to be 3 feet thick, the middle third being rather dirty. What is probably the Lower Banner is at least 3 feet thick on the upper part of Laurel Branch (location 481, elevation 2,396 S.) and is reported to be 44 inches thick.

WEAVER AND DUMPS CREEKS.

Geologic outline.—The area to be described includes only the drainage basins of Hart and Musick creeks, the valley of Weaver Creek itself and the region east of it being in faulted and folded pre-Pennsylvanian rocks, and Hurricane and Road forks of Dumps Creek. The Pennsylvanian rocks exposed include all of the series from its base to beds about 200 feet above the base of the Wise formation, but the Lee and the lower 200 feet of the Norton formation can be seen only southeast of the great fault, in the district in which they have been overturned and thrust up over younger strata. These rocks, shown on the geologic map in the undifferentiated Pennsylvanian pattern, dip steeply to the southeast at angles of 30 to 70 degrees, so that it is impossible to ascertain the exact stratigraphic succession in an area so heavily forested. The succession in less disturbed areas is shown by the columnar section for the south third of the Bucu quadrangle (Pl. IV), by numerous drill logs (Pl. III), and by local sections 12 and 29.

West of the faulted area dips are relatively very low and the structure is dominated by the Sourwood Mountain anticline, the axis of which trends from south to north. Dips are, in general, to the east on the east side of the anticline and to the west or northwest on the west side. Even near the fault the beds are not much disturbed, for the break appears to have been a sharp one that had little effect on the rocks on the northwest side of it.

This area contains some very important coal deposits. (See figs. 4, 5, and 21.) The Tiller and Jawbone beds are concealed below the surface in most of the region, but are believed to be thick, for reasons stated later. There are several coal beds between the Jawbone and Lower Banner beds, but they are thin in most places. The Garden Hole bed, however, is 3 to 4 feet thick, exclusive of partings, at the head of Skeen Creek, and the Kennedy about 3 feet thick in a few places.

The Lower and Upper Banner coal beds are being mined on a large scale at Wilder by the Clinchfield Coal Corporation. Mine 55, in the Lower Banner bed on both sides of Laurel Branch, is in coal $3\frac{1}{2}$ to $4\frac{1}{2}$ feet thick. Mine 6 in the Upper Banner is on the south side of Laurel Branch in coal 4 to $7\frac{1}{2}$ feet thick, and an entry being driven southwest under Sandy Ridge toward the workings of mine 2 at the head of McClure River is in similarly thick coal. Both these mines are modern and well equipped in every way and have a large producing capacity. The product is shipped over a short spur of the C. C. & O. Railway to Kiser, on the N. & W. Railway. Elsewhere in the Road Fork district the Lower Banner is 3 to 7 feet thick, but

it is thinner in the Hart Creek district. Outside the mining district near Wilder a thickening of a shale parting separates the Upper Banner into two parts, the lower one of which is commonly worthless and the upper 2 to 4 feet thick. There are probably localities in which Norton coal beds higher than the Upper Banner, especially the Splash Dam, are 2 or 3 feet thick, but the only exposures seen were too thin to be considered workable. Beds in the Wise formation on Sandy Ridge may be fairly thick in places.

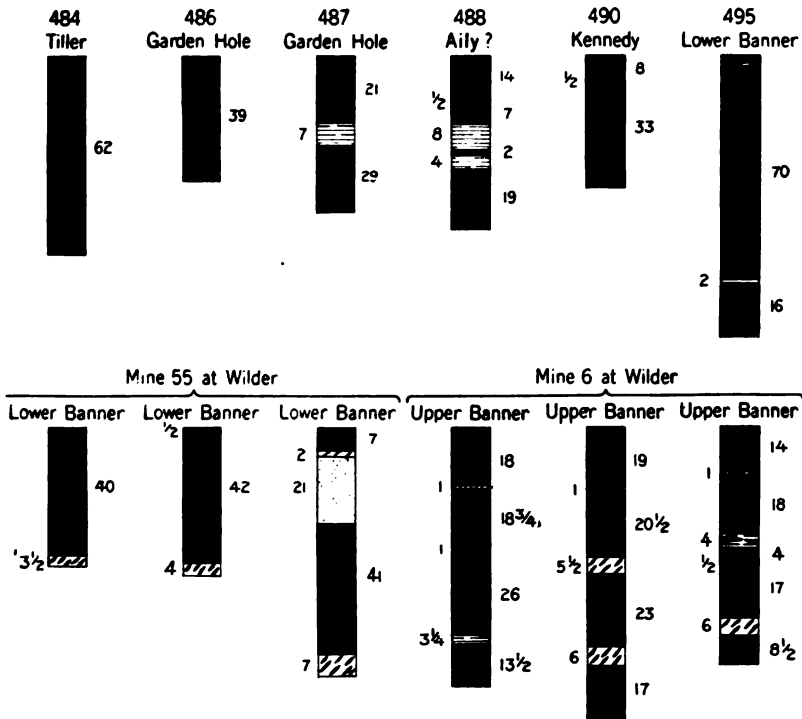


Fig. 21.—Sections of coal beds in the drainage basins of Weaver and Dumps creeks.

Outcrops not correlated.—Exposures are poor in the steeply dipping rocks mapped as undifferentiated Pennsylvanian and few coal beds were found among them. This fact is probably due in part, however, to a lack of thick coal deposits in the Lee formation of this area. One caved opening near the south boundary of the Bucu quadrangle (location 482, elevation 2,120 B.) is said to have been in coal a little more than 4 feet thick, but this report could not be verified. Another coal exposure, which may be of

the same bed, was found on a northeastern tributary of Hart Creek (location 483, elevation 1,950 B.), where coal 4 feet thick was seen and the total thickness may be 5 or 6 feet. The bed dips S. 35° E. at about 55° and is separated from a 50-foot, locally conglomeratic sandstone by about 2 feet of shale containing plants of lower Norton age. The fact that the shale, though now under the coal, has the characteristics of material overlying a coal bed indicates that the beds are overturned. The relations of the coal bed strongly resemble those of the Tiller.

Tiller and Jawbone coal beds.—The Tiller coal lies 850 to 950 feet below the Upper Banner horizon. The Jawbone is as much as 100 feet above the Tiller in parts of this area but, as shown by drill records (Pl. III), the two beds unite under a large part of the Hurricane Fork drainage basin. Where the beds are separated the interval between them is occupied chiefly by coarse-grained, siliceous sandstone that contains quartz pebbles. Both beds are below the surface except near the fault along Musick Creek, where the Tiller is 5 feet or more thick and the Jawbone probably thin. Where the two beds are united under part of the Hurricane Fork area they are probably much like the thick and valuable double bed that is exposed north of Sandy Ridge along the headwaters of Indian and Cane creeks. Both of the beds are probably also workable in much of the area in which they are separate; for the Jawbone includes 3½ to 8 feet of coal where it comes to the surface along Hurricane Fork south of and near the Bucu quadrangle and the Tiller is 4 to 5 feet thick at the "slope mine" of the Clinchfield Coal Corporation, the main entry of which has been driven nearly as far north as the quadrangle boundary south of Taylor triangulation station. The Jawbone coal is somewhat dirty along its outcrop.

The Tiller is 62 inches thick in a small mine 1.7 miles from the mouth of Musick Creek (location 484, elevation 1,850 B.), and has an overlying sandstone cap-rock more than 50 feet thick. A natural exposure of the same bed 1,200 feet down the creek contains 66 inches of coal at one end and twice as much at the other, the greater thickness probably being caused by folding. Coal in a small drift on the Tiller beside the Sourwood Mountain road (location 485, elevation 1,820 B.) is more than 57 inches thick.

Garden Hole and associated coal beds.—The Garden Hole coal bed, which is the lowest one exposed in most of this area, is 600 to 700 feet below the Upper Banner horizon and 150 to 230 feet above the Jawbone. It is below the surface along Road Fork and Hart Creek, except in the steeply dipping area, but is exposed along Hurricane Fork and Musick Creek

nearly to their heads. It is an excellent bed containing 3 to 4 feet of coal at the head of Skeen Creek, but is less than 30 inches thick elsewhere and is less than 14 inches thick in some localities. Two measurements were made near the head of Skeen Creek, the one farther north (location 486, elevation 2,210 C. C. C.) showing coal 39 inches thick. The other section, made at a small mine near the wagon road (location 487, elevation 2,210 C. C. C.), includes a 7-inch shale parting with coal 21 inches thick above it and 29 inches thick below it. The roof is an 8-inch draw shale under sandstone.

There are several more or less lenticular coal beds between the Garden Hole and the Jawbone and between the Garden Hole and the Kennedy, but none of them is of much commercial importance, as a thickness of as much as 2 feet is exceptional. The thickest measurement obtained is the following, which may be the Aily bed, here only 40 feet below the Kennedy horizon:

Section of Aily (?) coal bed on Sourwood Mountain.

(Location 488.)

	Ft.	in.
Shale	3	
Coal	1	2
Shale		$\frac{1}{2}$
Coal		7
Shale		8
Coal		2
Shale		4
Coal	1	7
Coal	3	6
Partings	1	$\frac{1}{2}$

Kennedy coal bed.—The Kennedy is 300 to 380 feet below the Upper Banner horizon. It is a very thin and commercially unimportant bed in most of this area, but is moderately thick at a few places. In an opening by the road on Hart Creek (location 489, elevation 1,948 S.) coal 30 inches thick may possibly be the Kennedy. The bed is exceptionally thick at the head of a tributary of Hurricane Fork, a mile west of Dumps Creek School (location 490, elevation 2,340 B.), where it is 41½ inches thick, including half an inch of shale, and has a sandy shale roof at least 8 feet thick. The coal is only 23 inches thick in a railroad cut near Wilder (location 491, elevation 2,070 B.), and is overlain by a 50-foot bed of fine-grained sandstone and underlain by coarser sandstone of the same thickness.

Lower Banner coal bed.—The Lower Banner coal is 200 to 270 feet above the Kennedy and 100 to 140 feet below the Upper Banner. It has

been spared by erosion only along Hart Creek and on the ridges on both sides and at the head of Road Fork. In the latter district it is being mined on a large scale by the Clinchfield Coal Corporation, and is a clean bed containing about 3 to 7 feet of coal and very little shale in the form of partings. In the Hart Creek district it is thin in most places, though fairly thick in the pits described below.

The Lower Banner is at least 3 feet thick, and perhaps thicker, in a pit near the level of Hart Creek three-quarters of a mile southeast of Rasnake (location 492, elevation 2,125 B.). An opening at the head of the branch of Musick Creek at Rasnake (location 493, elevation 2,450 H. L.) shows 2 benches of 15-inch coal separated by clay shale 8 inches thick. The roof is a thick sandstone bed.

The following two sections show the character of the bed between Hurricane and Road forks, though the first is thinner than the average and the second is exceptionally thick. The first section is at the south boundary of the quadrangle, at the head of a tributary of Hurricane Fork: the second is on a spur near the mouth of Negro Camp Branch.

Sections of Lower Banner coal bed on east side of Road Branch.

(Location 494, elevation 2,445 B.)			(Location 495, elevation 2,290 B.)		
	Ft.	in.		Ft.	in.
Shale	20		Shale	4	
Coal		6	Coal, dirty at top ..	5	10
Shale		11	Clay		2
Coal	2	2	Coal, reported	1	4
Shale		½			
Coal		11	Coal	7	2
			Parting		2
Coal	3	7			
Partings		11½			

In most parts of mine 55 of the Clinchfield Coal Corporation, on both sides of Laurel Branch near Wilder (one entrance at location 496, elevation 2,275 C. C. C.), the Lower Banner is 3½ to 4½ feet thick and shale partings are absent or very thin. The floor is, in general, a compact shale and the roof either shale or sandstone. Thin layers of "rash" occur both at the top and at the bottom of the coal. Analyses of mine samples are given elsewhere in this report.

Upper Banner coal bed.—The distribution of the Upper Banner is much the same as that of the Lower Banner. In the Hart Creek district and the northern part of the Road Fork drainage basin the bed is split into two parts by the thickening of a shale parting, the upper bench being 2 to 4

feet thick and the lower bench worthless or nearly so. Near Wilder, and especially south of Laurel Branch, the shale parting thins to a few inches and both benches can be easily mined together. In the Wilder district the layers of coal aggregate 4 to 7½ feet in thickness and are being mined on a large scale.

The character of the upper bench of the bed in the Hart Creek district is shown by the following two sections:

Sections of upper bench of Upper Banner coal bed near Rasnake.

(Location 497, elevation 2,340 B.)

	Ft.	in.
Sandstone	20	
Coal		2
Shale		3
Coal		6
Sandstone		1
Coal	2	4
Coal	3	
Partings		4

(Location 498, elevation 2,460 B.)

	Ft.	in.
Shale		
Coal		3
Shale		1
Coal		4
Sandstone		1
Coal	1	10
Coal	2	5
Partings		2

The details of the Upper Banner bed where both parts are united are illustrated by the following measurements made in mine 6 of the Clinchfield Coal Corporation, the workings of which are south of Laurel Branch (main entrance at location 499, elevation 2,402 C. C. C.):

Sections of Upper Banner coal bed in mine 6 at Wilder.

	Ft.	in.		Ft.	in.
Shale			Sandstone		
Coal	1	7	Coal	1	2
Sandstone		1	Sandstone		1
Coal	1	8½	Coal	1	6
"Rash"		5½	"Rash"		4
Coal	1	11	Coal		4
"Rash"		6	Shale		½
Coal	1	5	Coal	1	5
Shale			"Rash"		6
Coal	6	7½	Coal		8½
Partings	1	½	Shale		
			Coal	5	1½
			Partings		11½

AMOUNT OF ULTIMATELY AVAILABLE COAL.

Actual mining operations in Europe have shown that coal of lower grade than that in southwest Virginia can be profitably mined in beds only 14 inches thick and at depths greater than any to which it would be necessary to shaft for any bed in these quadrangles. The tonnages in the following table, therefore, include parts of beds in which the aggregate thickness of coal layers is 14 inches or more, and are on the basis of 1,800 tons of coal per acre-foot.

Although these tables were carefully prepared by T. K. Harnsberger, they are necessarily only rough estimates. The figures for beds which are below the surface in large areas are, of course, most likely to be in error. The calculated totals, though enormous, are thought to be very conservative estimates. The amount of coal already mined or made unavailable by mining operations is comparatively so small as to be negligible, being only one or two hundredths of one per cent of the total original tonnage.

Amount of coal in the Virginia portion of the Clintwood and Bucu quadrangles.

Clintwood quadrangle.		
Wise formation:	Acres.	Tons.
Clintwood	6,250	37,125,000
Eagle	6,720	27,059,000
Glamorgan	27,610	87,708,000
Other beds		85,622,000
Norton formation:		
Splash Dam	66,110	224,415,000
Upper Banner	88,830	427,201,000
Lower Banner	99,220	381,973,000
Other beds above Kennedy		155,568,000
Kennedy	94,700	340,306,000
Garden Hole	106,190	423,189,000
Jawbone	90,160	418,630,000
Other beds below Kennedy		369,492,000
Lee formation:		
All beds		1,498,740,000
		4,477,037,000
Bucu quadrangle.		
Wise formation:	Acres.	Tons.
Clintwood	2,680	10,800,000
Eagle	3,750	28,698,000
Glamorgan	10,830	40,026,000
Other beds		43,132,000
Carried forward		122,656,000

	Acres.	Tons.
Brought forward .....	.....	122,656,000
Norton formation:		
Splash Dam	47,480	186,929,000
Upper Banner	26,720	117,852,000
Lower Banner	42,720	169,139,000
Other beds above Kennedy.....	.....	130,035,000
Kennedy	103,110	446,227,000
Garden Hole	116,670	427,602,000
Jawbone	122,960	536,657,000
Tiller	122,720	529,916,000
Other beds below Kennedy.....	.....	1,091,461,000
Lee formation:		
All beds .....	.....	2,131,908,000
		5,890,382,000

Of the grand total of 10,367,419,000 tons, only about 60 per cent would be recovered, even under the most favorable mining conditions, leaving about 6,220,450,000 tons as a possible production. At the present rate of consumption of bituminous coal, this would supply all of the United States for thirteen or fourteen years. It must be remembered, however, that much of this coal is in beds that are too thin or too far beneath the surface to be profitably mined and sold in competition with coal from more cheaply mined beds now being exploited in the Appalachian coal field. Beds which can not be used to-day, however, are certain to be highly valued at some time in the future.

CHARACTERS AND QUALITY OF THE COALS.

Analyses.

METHOD OF SAMPLING AND ANALYZING.

The analyses on succeeding pages were made from samples collected by members of the State and Federal geological surveys and the United States Bureau of Mines in the Clintwood and Bucu quadrangles or neighboring areas on the west and south. Samples collected before July 1, 1910, were analyzed by the United States Geological Survey, and those taken after that date by the United States Bureau of Mines.

In taking a sample of coal for analysis every effort was made to procure fresh, unweathered coal that would represent as nearly as possible the product of the mine. The bed was faced up and carefully cleaned, for a distance of three feet or more on each side of the point selected for sampling, special care being taken to remove all loose fragments of "slate" from the roof and deposited powder smoke from the coal. A uniform cut, of sufficient

size to yield about 6 pounds of coal for each foot of thickness of the bed, was then made from roof to floor. All partings or binders more than three-eighths of an inch thick and all concretions or "sulphur-balls" having a maximum diameter greater than 2 inches and a thickness of more than half an inch were excluded from the sample. The material thus obtained was crushed until it would pass through a $\frac{1}{2}$ -inch mesh and was then thoroughly mixed and reduced by quartering until about 4 pounds remained. The product was placed in a galvanized-iron can, sealed in the mine with adhesive tape, and mailed as soon as possible to the laboratory.

As soon as received at the laboratory, the coal is taken from the can, weighed, and allowed to dry at a temperature slightly above normal until its weight becomes practically constant. It is then reweighed, the difference in weight being the air-drying loss. Because the coal is more stable and more easily handled in the air-dried form, it is analyzed in this condition and the results given under form B. Forms A, C, and D are calculated from form B. Form A represents the coal as it is collected. Form C represents the theoretical condition of the coal if all the moisture were removed, and form D if both moisture and ash were removed.

DESCRIPTION OF SAMPLES.

18239, 18240, 18241, and 18242.—Samples were collected in No. 201 slope mine of the Clinchfield Coal Corporation, on Hurricane Fork of Dumps Creek, about 1 mile south of the Bucu quadrangle, November 26, 1913. Sample 18239 was obtained in the main entry, 4,900 feet N. 30° W. of bottom of slope; sample 18240, about 1,200 feet N. 64° W. of slope and 800 feet west of main entry; and sample 18241 in a right heading about 800 feet from main entry and 2,600 feet N. 20° W. of slope. Sample 18242 was a composite made by mixing 18239, 18240, and 18241.

Sections of Tiller coal bed at points sampled in Clinchfield No. 201 mine.

	18239		18240		18241	
	Ft.	in.	Ft.	in.	Ft.	in.
"Rash"	*0	9	..	..	..	..
Coal	2	0	1	$9\frac{1}{2}$	1	$4\frac{1}{2}$
Shale	..	..	*0	5	*0	$3\frac{1}{2}$
Sandstone	*0	3	..	..	..	..
Coal	3	1	2	3	2	3
Included in sample	5	1	4	$\frac{1}{2}$	3	$7\frac{1}{2}$
Excluded from sample.....	1	0	0	5	0	$3\frac{1}{2}$

* Not included in sample.

5217 and 5235.—Samples were collected in the Virginia City No. 1, a slope mine at Virginia City, Va., July 26, 1907. Sample 5217 was obtained in room 8, off the first cross-heading, 2,400 feet northwest of mine opening; sample 5235, in a break-through between the third and fourth cross-entries, 3,200 feet northwest of mine opening.

Sections of Jawbone coal bed at points sampled in Virginia City No. 1 mine.

	5217		5235	
	Ft.	in.	Ft.	in.
Coal	0	6½	0	5
Sandstone	..	..	*0	¼
"Rash"	*0	2	..	..
Coal	1	9½	0	2
"Rash"	..	..	*0	½
Bone coal	0	2	..	..
Coal	1	5	1	4½
Shale and coal	..	..	*0	7
Bone coal	0	2	0	3
Coal	4	½	4	6
Included in sample	8	1½	6	8½
Excluded from sample	0	2	0	7¾

22346.—Sample collected in the Jackson mine, a small local drift mine, 3 miles northwest of Honaker, Va., and near the southeast corner of the Bucu quadrangle (location 474 on map), May 25, 1915. The sample was obtained in the first right entry, 600 feet northwest of mine opening.

Section of coal bed at point sampled in Jackson mine.

	22346	
	Ft.	in.
Coal	1	0
"Rash"	0	¾
Coal	1	9½
Clay	*0	½
Coal	0	7
Included in sample	3	4¾
Excluded from sample	0	½

18121-F.—Sample collected from the Kennedy coal bed in mine No. 103 of the Clinchfield Coal Corporation, 1 mile northwest of Dante, Va., November 17, 1913. The sample was obtained in the main entry, 260 feet N. 55° W. of mine opening and represents 5 feet 2 inches of coal, the entire thickness of the bed.

* Not included in sample.

17559, 17560, and 17561-F.—Samples collected from a small local drift mine, half a mile north of Nora (location 139 on map), July 12, 1913. Sample 17559 was cut 300 feet east of drift mouth; and sample 17560, about 300 feet northeast of drift mouth. Sample 17561-F was a composite made by mixing 17559 and 17560.

Sections of Kennedy coal bed at points sampled in mine half a mile north of Nora.

	17559		17560	
	Ft.	in.	Ft.	in.
Coal	0	6 $\frac{3}{8}$	0	5 $\frac{1}{2}$
Bone	0	$\frac{1}{4}$	0	$\frac{1}{8}$
Coal	1	3	0	6 $\frac{1}{4}$
"Rash"	0	$\frac{1}{8}$	..	..
Shale	..	..	0	1 $\frac{3}{4}$
Coal	0	3 $\frac{3}{4}$	0	5 $\frac{3}{4}$
"Rash"	0	$\frac{1}{4}$	..	..
Bone	..	..	0	$\frac{1}{4}$
Coal	0	2 $\frac{5}{8}$	0	8
"Rash"	0	$\frac{1}{8}$	..	..
Coal	0	4	..	..
Included in sample	2	8 $\frac{1}{2}$	2	1 $\frac{7}{8}$
Excluded from sample.....	0	0	0	1 $\frac{3}{4}$

19484.—Sample collected from the Kennedy coal bed in the Drill mine of the Honaker Lumber Company at Drill (location 475 on map), June 5, 1914. The sample was cut about 450 feet northeast of drift mouth, and represents 4 feet of coal, the entire thickness of the bed.

22345-F.—Sample collected from the Kennedy coal bed in the Sandy Ridge mine of the Sandy Ridge Coal & Coke Company, three-quarters of a mile south of Drill (location 477 on map), May 25, 1915. The sample was cut in the north drift, 170 feet S. 70° W. of entrance, and represents 2 feet 9 inches of coal, the entire thickness of the bed.

19528.—Sample collected from the Kennedy coal bed in the Sandy Ridge mine of the Sandy Ridge Coal & Coke Company, three-quarters of a mile south of Drill (location 477), June 15, 1914. The sample was obtained from the south drift in room off main entry, 150 feet north of mine mouth, and represents 2 feet 10 inches of coal, the entire thickness of the bed.

18122, 18123, and 18124-F.—Samples were collected in mine No. 52 of the Clinchfield Coal Corporation at Dante, Va., November 17, 1913.

* Not included in sample.

Sample 18122 was cut 325 feet northeast of entrance to No. 0 drift; and sample 18123, about 1,700 feet southwest of entrance to No. 1 drift. Sample 18124-F was a composite obtained by mixing 18122 and 18123.

Sections of Lower Banner coal bed at points sampled in Clinchfield No. 52 mine.

	18122		18123	
	Ft.	in.	Ft.	in.
Coal	3	0	2	6½
Coal and shale.....	..	..	*0	2
Included in sample.....	3	0	2	6½
Excluded from sample.....	0	0	0	2

10385.—Sample collected from the Lower Banner bed in mine No. 52 (called Clinchfield when sampled) of the Clinchfield Coal Corporation at Dante, Va., April 30, 1910. The sample was cut in the main entry, 150 feet from the mine mouth, and represents 2 feet 4 inches of coal.

4057.—Sample was collected in mine No. 51 (called No. 2 when sampled) of the Clinchfield Coal Corporation at Dante, Va., October 4, 1906. The sample was obtained in room 4 off the left entry.

Section of Lower Banner coal bed at point sampled on Clinchfield No. 51 mine.

	4057	
	Ft.	in.
Coal, alternate bright and dull bands.....	1	7
Coal, laminated	0	3
Coal, solid	1	5
Clay	*0	6
Coal, bright	*0	2
Included in sample.....	3	3
Excluded from sample.....	0	8

18243, 18244, 18245, and 18246.—Samples collected in mine No. 55 of the Clinchfield Coal Corporation at Wilder, Va. (location 496 on map), November 25, 1914. Sample 18243 was obtained 900 feet S. 60° W. of No. 3 opening; sample 18244, about 2,500 feet S. 35° E. of No. 5 opening; and sample 18245, about 1,300 feet N. 35° W. of No. 2 opening. Sample 18246 was a composite made by mixing 18243, 18244, and 18245.

* Not included in sample.

Sections of Lower Banner coal bed at points sampled in Clinchfield No. 55 mine.

	18243		18244		18245	
	Ft.	in.	Ft.	in.	Ft.	in.
Coal	..	..	0	7	..	..
"Rash"	..	..	*0	2	..	..
Sandstone	..	..	*1	9	..	..
"Rash"	..	..	..	..	*0	½
Coal	3	4	3	5	3	6
"Rash"	*0	3½	*0	7	*0	4
Included in sample.....	3	4	4	0	3	6
Excluded from sample.....	0	3½	2	6	..	4½

18226, 18227, 18228, and 18229-F.—Samples were collected in the Cranesnest No. 1 mine of the Clinchfield Coal Corporation, about 1½ miles northwest of Toms Creek station, November 22, 1913. Sample 18226 was obtained 1,500 feet southwest of entrance to main Caney entry (location 114 on map); sample 18227, about 500 feet northeast of main Caney entry; and sample 18228, about 4,100 feet southeast of main Caney entry. The main Caney entry (location 114 on map) is on Hurricane Fork of Caney Creek, about 1½ miles northeast of the main entrance to mine. Sample 18229-F was a composite made by mixing 18226, 18227, and 18228.

Sections of Upper Banner coal bed at points sampled in Cranesnest mine.

	18226		18227		18228	
	Ft.	in.	Ft.	in.	Ft.	in.
Coal	0	1½	..	..	..	..
Sandy shale	*0	½	..	..	..	..
Coal	2	0	1	10	2	10
Sandstone	*0	1	*0	1	*0	1
Coal	1	7½	2	2	1	5¾
Coal and shale.....	*0	2½	..	..	..	..
Shale	..	..	..	..	0	¼
Coal	0	3½	..	..	0	3
Shale	*0	4	..	..	*0	5
Coal	0	2	..	..	0	6
Shale	*0	1¾	..	..	0	⅞
Coal	0	10	..	..	0	9½
Included in sample.....	5	½	4	0	5	10⅞
Excluded from sample.....	0	9¾	0	1	0	6

10386.—Sample collected from the Swansea mine of the Virginia Iron, Coal & Coke Company, Toms Creek, Va., April 29, 1910. The sample was taken in room 21, off west entry 17, about 2,600 feet from the outcrop.

* Not included in sample.

Section of Upper Banner coal bed at point sampled in Swansea mine.

		10386	
		Ft.	in.
Coal		2	4
Sandstone		*0	1½
Coal		1	8
Bone		*1	5
Coal		2	7
Included in sample.....		6	7
Excluded from sample.....		1	6½

2281 and 2282.—Samples collected from the Coeburn mine of the Virginia Iron, Coal & Coke Company at Toms Creek, Va., October 7, 1905. Sample 2281 was obtained in east heading 17, about 3,000 feet northeast of the mine opening; and sample 2282 in room 3, off west entry 11, about 2,000 feet northeast of mine opening.

Sections of Upper Banner coal bed at points sampled in Coeburn mine.

		2281		2282	
		Ft.	in.	Ft.	in.
Coal		2	2½	0	10
Sandstone		*0	1½	..	..
Mother coal		..	..	0	¼
Coal		1	6	1	6
Shale		*0	1½	..	..
Sandstone		..	..	*0	1
Coal		*0	2	1	8
Shale		*0	2	*0	1
Coal		*0	6	*0	2
Shale		*0	1½	*0	3
Coal		1	8	*0	6
Mother coal		0	¼	..	..
Shale		..	..	*0	1
Coal		1	0	2	7
Included in sample.....		6	4¾	6	7¼
Excluded from sample.....		1	2½	1	2

18128, 18129, 18130, 18131-F.—Samples collected in No. 2 mine of the Clinchfield Coal Corporation, 1¾ miles northeast of Dante, Va., November 18, 1913. Sample 18128 was obtained 2,400 feet N. 18° W. of entrance to drift No. 3, McClure; 18129, about 2,750 feet S. 78° E. of entrance to drift No. 5, tunnel line (on Middle Fork of Lick Creek); and 18130, about 3,400 feet S. 85° E. of entrance to drift No. 1, McClure. Sample 18131-F was a composite made by mixing 18128, 18129, and 18130.

* Not included in sample.

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Sections of Upper Banner coal bed at points sampled in Clinchfield No. 2 mine.

	18128		18129		18130	
	Ft.	in.	Ft.	in.	Ft.	in.
Coal	1	10	1	4	1	6
Sandstone	*0	1½	*0	1	*0	1
Coal	1	2½	1	2	1	5
Sandstone	*0	½	..	..	*0	1
Shale	..	..	*0	1	..	..
Coal	2	5	1	6	1	10
Included in sample	5	5½	4	0	4	9
Excluded from sample	0	2	0	2	0	2

10734, 10735, and 10736.—Samples collected in mine No. 2 of the Clinchfield Coal Corporation, 1¾ miles northeast of Dante, Va., August 13, 1910. Sample 10734 was obtained at face of butt-heading, off the fourth left drift off the McClure entry; and sample 10735 in room 16, off right heading 3, off the first drift off McClure entry. Sample 10736 was a composite made by mixing 10734 and 10735.

Sections of Upper Banner coal bed at points sampled in Clinchfield No. 2 mine.

	10734		10735	
	Ft.	in.	Ft.	in.
Coal	0	8½	0	6¾
Coal (hard)	0	3½	0	5
Coal	0	5¾	0	7
Sandstone	*0	¾	*0	1½
Coal	1	4	1	4
Shale	*0	¾	*0	2¾
Coal	0	5	0	6
Coal (hard)	0	5	0	3¾
Coal	1	5¼	1	1
Included in sample	5	1	4	9½
Excluded from sample	0	1½	0	4¼

10737, 10738, and 10739.—Samples collected in mine No. 5 of the Clinchfield Coal Corporation, 1½ miles northeast of Dante, Va., August 10, 1910. Sample 10737 was obtained at the face of room 14, right heading 5, off drift 9; and sample 10738, from the butt, on left heading 9, off drift 9. Sample 10739 was a composite obtained by mixing 10737 and 10738.

* Not included in sample.

Sections of Upper Banner coal bed at points sampled in Clinchfield No. 5 mine.

	10737		10738	
	Ft.	in.	Ft.	in.
Coal	0	4 $\frac{3}{4}$	1	10 $\frac{1}{2}$
Mother coal	..	..	0	$\frac{3}{8}$
Coal	1	4 $\frac{3}{4}$	0	4 $\frac{3}{8}$
Sandstone	*0	1 $\frac{1}{2}$	*0	1 $\frac{3}{4}$
Coal	0	10	0	4 $\frac{1}{2}$
Shale	*0	$\frac{3}{4}$	*0	1 $\frac{1}{2}$
Coal	1	4 $\frac{1}{4}$	1	1
Mother coal	0	$\frac{1}{8}$	..	..
Coal	1	$\frac{3}{8}$	1	6
Included in sample.....	5	1 $\frac{1}{4}$	5	3
Excluded from sample.....	0	2 $\frac{1}{4}$	0	2 $\frac{1}{4}$

10387.—Sample collected in mine No. 3 of the Clinchfield Coal Corporation at Dante, Va., April 30, 1910. The sample was obtained in the fourth right entry, 1,000 feet from mine mouth.

Section of Upper Banner coal bed at point sampled in Clinchfield No. 3 mine.

	10387	
	Ft.	in.
Coal	0	2 $\frac{1}{2}$
Parting	*0	2
Coal	1	6
Sandstone	*0	1
Coal	1	2 $\frac{1}{2}$
Parting	*0	1
Coal	1	11 $\frac{1}{2}$
Included in sample.....	4	10 $\frac{1}{2}$
Excluded from sample.....	0	4

3942.—Sample collected in mine No. 2 (called No. 3 when sampled) of the Clinchfield Coal Corporation, 1 $\frac{3}{4}$ miles northeast of Dante, October 4, 1906. The sample was cut in butt entry 6, off the main entry.

Section of Upper Banner coal bed at point sampled in Clinchfield No. 2 mine.

	3942	
	Ft.	in.
Coal	1	10
Sandstone	*0	1
Coal	0	10
Shale, gritty	*0	$\frac{1}{2}$
Coal	2	5
Included in sample.....	5	1
Excluded from sample.....	0	1 $\frac{1}{2}$

* Not included in sample.

18235, 18236, 18237, 18238.—Samples collected in mine No. 6 of the Clinchfield Coal Corporation at Wilder, Va. (location 499 on map), November 25, 1913. Sample 18235 was obtained 3,000 feet S. 71° W. of No. 1 drift; sample 18236 in room 5, about 1,250 feet S. 35° E. of No. 3 opening; and sample 18237, about 4,000 feet S. 10° W. of No. 3 opening. Sample 18238 was a composite obtained by mixing 18235, 18236, and 18237.

Sections of Upper Banner coal bed at points sampled in Clinchfield No. 6 mine.

	18235		18236		18237	
	Ft.	in.	Ft.	in.	Ft.	in.
Coal	1	6	1	2	1	7
Sandstone	*0	1	*0	1	*0	1
Coal	1	6¾	1	6¼	1	8½
Shale	*0	1	..	..	*0	1
Coal and shale.....	..	..	*0	4¼	..	..
"Rash"	..	..	..	..	*0	4½
Coal	2	2	0	4¼	1	11
Shale	*0	3¼	*0	½	..	..
"Rash" and clay.....	..	..	..	..	*0	6
Coal	1	1½	1	5	1	5
Coal and shale.....	..	..	*0	6	..	..
Coal	..	..	0	8½	..	..
Included in sample.....	6	4¼	5	2	6	7½
Excluded from sample.....	0	5¼	0	11¾	1	½

17751 and 17752.—Samples collected from small local drift mine of C. C. Owens on Russell Prater Creek, 1 mile above mouth (location 345 on map), September 19, 1913. Sample 17751 was obtained 75 feet east of drift mouth and 10 feet north of main drift; sample 17752, about 25 feet south of 17751.

Sections of Splash Dam coal bed at points sampled in C. C. Owens mine.

	17751		17752	
	Ft.	in.	Ft.	in.
Coal	0	8½	1	8
"Rash"	0	¼	..	..
Shale	..	..	*0	½
Coal	0	11	0	2
Shale	0	¼	*0	1
Coal	0	2	0	3½
Shale	*0	1¼	..	..
Shale and pyrites.....	..	..	0	¼
Coal	0	7½	0	4
Included in sample.....	2	5½	2	5¾
Excluded from sample.....	0	1¼	0	1½

* Not included in sample.

15100 and 15101.—Samples collected in Glamorgan No. 3 mine of the Stone Gap Colliery Company at Glamorgan, Va., November 5, 1912. Sample 15100 was obtained at the face of the second dip entry, 6,000 feet from the mine mouth; sample 15101, at the face of the Gladly entry, 7,000 feet from the mine mouth.

Sections of Glamorgan coal bed at points sampled in Glamorgan No. 3 mine.

	15100		15101	
	Ft.	in.	Ft.	in.
Coal	1	9	..	..
Bone	*0	1	..	..
Coal	1	10	3	8
Bone	*0	1½	*0	1
Coal	0	8	0	7
Included in sample.....	4	3	4	3
Excluded from sample.....	0	2½	0	1

17743 and 17744.—Sample collected in small local drift mine of the Yellow Poplar Lumber Company on Slate Branch of Barts Lick Creek, 3 miles east of the mouth of Pound River (location 387 on map), September 17, 1913. Sample 17743 was obtained 200 feet east of entrance to mine; and sample 17744, about 220 feet N. 85° E. of entrance to mine.

Sections of Eagle coal bed at points sampled in Yellow Poplar Lumber Co. mine.

	17743		17744	
	Ft.	in.	Ft.	in.
Coal, pyritiferous	*0	8	*0	9½
Shale	*0	7	*0	6½
Coal	0	3	0	3
"Rash"	0	¾	0	¾
Coal	0	9½	0	8½
Bone	*0	1	*0	1
Coal	1	1½	1	2¾
Sandstone	*0	1½	*0	1
Coal	1	3	1	3½
Included in sample.....	3	5½	3	5¾
Excluded from sample	1	5½	1	6

14767.—Sample collected in Elbert Powers small local drift mine on Big Ridge, 5½ miles south of Clintwood, Va. (location 73 in map), September 17, 1912. The sample was cut 20 feet from the drift mouth.

* Not included in sample.

Section of Clintwood coal bed at point sampled in Elbert Powers mine.

		14767	
		Ft.	in.
Coal	.....	*2	7½
Bone	.....	*0	7
Coal	.....	1	11
"Rash"	.....	0	¾
Coal	.....	0	3½
"Rash"	.....	0	¾
Coal	.....	2	4
Included in sample.....		4	8
Excluded from sample.....		3	2½

14766.—Sample collected in John A. Yeates small local drift mine, 1 mile southwest of Clintwood, Va., September 21, 1912. The sample was cut at the end of right entry 1, off the main entry, and 100 feet from the main entry.

Section of Clintwood coal bed at point sampled in Yeates mine.

		14766	
		Ft.	in.
Bone	.....	0	1
Coal	.....	0	9
Bone	.....	0	2
Coal	.....	0	8½
Bone	.....	0	1¼
Coal	.....	0	3½
Bone	.....	0	1½
Coal	.....	0	3
Bone	.....	0	1
Coal	.....	1	8
Included in sample		4	2¾

3827.—Sample collected in the Chase and Damron local drift mine, three-quarters of a mile south of Clintwood, Va. (location 65 on map), September 21, 1906. The sample was taken at the face of a drift about 150 feet from the main entry.

Section of Clintwood coal bed at point sampled in Chase and Damron mine.

		3827	
		Ft.	in.
Coal	.....	4	4
Pyrite	.....	*0	2
Coal	.....	*1	9
Included in sample		4	4
Excluded from sample.....		1	11

* Not included in sample.

Table of analyses of coal samples from mines in and near the Clintwood and Bucu quadrangles, Virginia.

A = analysis of sample as received, B = air-dried, C = moisture free, D = moisture and ash free.

Coal bed.	Name and location of mine.	Collector.	Laboratory No.	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heating Value.	
						Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
Tuller.....	No. 201 of the Clinchfield Coal Corporation on Hurricane Fork of Dumps Creek.	T. K. Harnsberger..	18239	1.0	A	1.8	31.4	60.3	6.5	0.22	.....	.....	.....	.....	7,890	14,180
					B	.8	31.8	60.9	6.5	.53	.....	.....	.....	.....	7,900	14,380
					C	.....	32.0	61.4	6.6	.53	.....	.....	.....	.....	8,025	14,440
					D	.....	34.3	65.7	.....	.57	.....	.....	.....	.....	8,500	15,460
Do.....	do.....	do.....	18240	1.8	A	2.5	31.9	59.5	6.1	.44	.....	.....	.....	.....	7,890	14,070
					B	.8	32.4	60.6	6.2	.45	.....	.....	.....	.....	7,900	14,880
					C	.....	32.7	61.1	6.2	.45	.....	.....	.....	.....	8,020	14,480
					D	.....	34.9	65.1	.....	.48	.....	.....	.....	.....	8,555	15,400
Do.....	do.....	do.....	18241	1.9	A	2.4	32.5	58.4	6.7	.49	.....	.....	.....	.....	7,700	14,020
					B	.6	33.1	59.5	6.8	.50	.....	.....	.....	.....	7,940	14,290
					C	.....	33.8	59.8	6.9	.50	.....	.....	.....	.....	7,965	14,880
					D	.....	35.7	64.3	.....	.54	.....	.....	.....	.....	8,575	15,440
Do.....	do.....	do.....	18242	1.6	A	2.2	31.9	59.4	6.50	.46	5.11	79.69	1.04	7.20	7,840	14,110
					B	.6	33.5	60.3	6.60	.47	5.02	80.94	1.05	5.91	7,980	14,380
					C	.....	32.7	60.7	6.65	.47	4.98	81.48	1.05	5.86	8,015	14,480
					D	.....	35.0	65.0	.....	.50	5.33	87.28	1.14	5.75	8,585	15,460
Jawbone.....	Virginia City No. 1, at Virginia City, Va.	K. M. Way.....	5217	2.2	A	3.4	29.6	53.1	14.9	1.18	.....	.....	.....	.....	6,915	12,450
					B	1.2	29.3	54.3	15.2	1.20	.....	.....	.....	.....	7,080	12,710
					C	.....	29.6	54.9	15.5	1.22	.....	.....	.....	.....	7,155	12,880
					D	.....	35.0	65.0	.....	1.44	.....	.....	.....	.....	8,470	15,240
Do.....	do.....	do.....	5235	1.8	A	3.1	27.8	54.2	14.9	1.24	.....	.....	.....	.....	6,895	12,410
					B	1.3	29.3	55.2	15.2	1.26	.....	.....	.....	.....	7,020	12,640
					C	.....	29.7	55.9	15.4	1.28	.....	.....	.....	.....	7,115	12,800
					D	.....	33.9	65.1	.....	1.51	.....	.....	.....	.....	8,410	15,140
Ally(?)	Jackson, a small local mine, 3 miles north-west of Honaker, Va.	T. K. Harnsberger..	22346	1.1	A	2.5	34.2	59.7	12.6	.94	.....	.....	.....	.....	7,140	12,850
					B	1.4	34.6	51.3	12.7	.95	.....	.....	.....	.....	7,215	12,990
					C	.....	35.1	52.0	12.9	.96	.....	.....	.....	.....	7,880	13,170
					D	.....	40.3	59.7	.....	1.10	.....	.....	.....	.....	8,410	15,140

Table of analyses of coal samples from mines in and near the Clintwood and Bucu quadrangles, Virginia—Contd.

Coal bed.	Name and location of mine.	Collector.	Laboratory No.	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.				Heating Value.		
						Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
Kennedy.....	No. 103 of the Clinchfield Coal Corporation, 1 mile northwest of Dante, Va.	T. K. Harnsberger..	18121F	1.9	A	2.9	31.9	57.8	7.4	1.78	.....	.....	.....	7,655	13,780	
					B	1.0	32.5	58.9	7.6	1.81	.....	.....	.....	7,800	14,040	
					C	.....	32.8	59.6	7.6	1.83	.....	.....	.....	7,880	14,180	
					D	.....	35.5	64.5	.....	1.88	.....	.....	.....	8,535	15,360	
Do.....	Small local mine on McClure River, ¼ mile north of Open Fork.	Henry Hinds	17559	1.8	A	2.6	25.5	61.0	10.9	.70	.....	.....	.....	7,470	13,440	
					B	.9	25.9	62.1	11.1	.71	.....	.....	.....	7,605	13,600	
					C	.....	26.1	62.7	11.2	.72	.....	.....	.....	7,670	13,810	
					D	.....	29.5	70.5	.....	.81	.....	.....	.....	8,640	15,550	
Do.....	do.....	do.....	17560	1.7	A	2.6	26.0	63.2	8.2	.73	.....	.....	.....	7,725	13,910	
					B	.9	26.5	64.3	8.3	.74	.....	.....	.....	7,860	14,150	
					C	.....	26.7	64.9	8.4	.75	.....	.....	.....	7,935	14,290	
					D	.....	29.2	70.8	.....	.82	.....	.....	.....	8,680	15,560	
Do.....	do.....	do.....	17561F	1.8	A	2.6	26.2	61.7	9.48	.74	4.75	77.00	1.57	5.86	7,575	13,640
					B	.9	26.6	62.8	9.65	.75	4.64	78.98	1.60	4.38	7,710	13,880
					C	.....	26.9	63.4	9.74	.76	4.58	79.70	1.61	3.61	7,780	14,010
					D	.....	29.8	70.2	.....	.84	5.07	86.30	1.78	4.01	8,620	15,520
Do.....	Honaker Lumber Company mine at Drill, Va.	O. M. Bauer.....	19484	.8	A	2.1	32.4	58.7	6.8	1.01	.....	.....	.....	.....	.....	.....
					B	1.3	32.6	59.2	6.9	1.02	.....	.....	.....	.....	.....	.....
					C	.....	33.1	60.0	6.9	1.03	.....	.....	.....	.....	.....	.....
					D	.....	35.5	64.5	.....	1.11	.....	.....	.....	.....	.....	.....
Do.....	Sandy Ridge Coal and Coke Company mine, ¾ of a mile south of Drill, Va.	T. K. Harnsberger..	22345F	3.5	A	4.7	30.8	59.4	5.14	.96	5.43	78.33	1.40	6.74	7,760	13,980
					B	1.2	31.9	61.6	5.33	1.00	5.22	81.18	1.45	5.82	8,040	14,470
					C	.....	32.3	62.3	5.39	1.01	5.15	82.17	1.47	4.81	8,140	14,650
					D	.....	34.1	65.9	.....	1.07	5.44	86.85	1.55	5.09	8,600	15,480
Do.....	do.....	O. M. Bauer.....	19698	1.8	A	3.2	33.1	57.7	6.0	.96	.....	.....	.....	.....	.....	.....
					B	1.4	33.7	59.8	6.1	.98	.....	.....	.....	.....	.....	.....
					C	.....	34.2	59.6	6.2	.99	.....	.....	.....	.....	.....	.....
					D	.....	36.4	63.6	.....	1.06	.....	.....	.....	.....	.....	.....

Table of analyses of coal samples from mines in and near the Clintwood and Bucu quadrangles, Virginia—Contd.

Coal bed.	Name and location of mine.	Collector.	Laboratory No.	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heating Value.	
						Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
Lower Banner ..	No. 52 of the Clinchfield Coal Corporation at Dante, Va.	T. K. Harnsberger ..	18122	1.6	A	2.5	35.6	56.2	5.7	0.66	.....	.....	.....	.....	7,980	14,280
					B	.9	36.1	57.2	5.8	.67	.....	.....	.....	.....	8,060	14,510
					C	.....	36.4	57.7	5.9	.68	.....	.....	.....	.....	8,135	14,640
					D	.....	38.7	61.3	.....	.72	.....	.....	.....	.....	8,640	15,560
Do.....	do.....	do.....	18123	1.1	A	2.0	35.7	54.5	7.8	.66	.....	.....	.....	.....	7,685	13,880
					B	.9	36.1	55.1	7.9	.67	.....	.....	.....	.....	7,770	13,960
					C	.....	36.4	55.6	8.0	.67	.....	.....	.....	.....	7,840	14,110
					D	.....	39.5	60.5	.....	.73	.....	.....	.....	.....	8,590	15,390
Do.....	do.....	do.....	18124 ^F	1.4	A	2.3	35.5	55.5	6.71	.67	5.26	78.84	1.69	6.83	7,780	14,000
					B	.9	36.0	56.3	6.80	.68	5.18	79.94	1.71	5.69	7,860	14,200
					C	.....	36.3	56.8	6.87	.69	5.13	80.66	1.73	4.92	7,960	14,390
					D	.....	39.	61.0	.....	.74	5.51	86.61	1.96	5.28	8,545	15,390
Do.....	No. 52 (Called Clinchfield when sampled) of the Clinchfield Coal Corporation at Dante, Va.	E. G. Woodruff	10885	1.1	A	2.1	33.7	57.7	6.45	.65	5.44	78.59	1.53	7.34	7,855	14,140
					B	1.0	34.2	58.3	6.62	.66	5.38	79.46	1.55	6.43	7,940	14,290
					C	.....	34.5	58.9	6.59	.66	5.31	80.30	1.56	5.58	8,025	14,440
					D	.....	36.9	63.1	.....	.71	5.68	85.96	1.67	5.98	8,590	15,460
Do.....	No. 51 (called No. 2 when sampled) of the Clinchfield Coal Corporation at Dante, Va.	R. W. Stone.....	4057	1.8	A	2.8	32.1	59.3	5.8	.84	.....	.....	.....	.....	.....	.....
					B	1.0	32.7	60.4	5.9	.85	.....	.....	.....	.....	.....	.....
					C	.....	33.0	61.0	6.0	.86	.....	.....	.....	.....	.....	.....
					D	.....	35.1	64.9	.....	.92	.....	.....	.....	.....	.....	.....
Do.....	No. 55 of the Clinchfield Coal Corporation at Wilder, Va.	T. K. Harnsberger ..	18243	2.4	A	3.1	33.7	57.3	5.9	.79	.....	.....	.....	.....	7,860	14,150
					B	.8	34.5	58.7	6.0	.81	.....	.....	.....	.....	8,050	14,490
					C	.....	34.8	59.1	6.1	.82	.....	.....	.....	.....	8,115	14,600
					D	.....	37.0	63.0	.....	.87	.....	.....	.....	.....	8,640	15,550
Do.....	do.....	do.....	18244	1.6	A	2.4	34.6	57.3	5.7	.83	.....	.....	.....	.....	7,945	14,300
					B	.8	35.2	58.3	5.7	.84	.....	.....	.....	.....	8,075	14,540
					C	.....	35.5	58.7	5.8	.85	.....	.....	.....	.....	8,140	14,660
					D	.....	37.6	62.4	.....	.90	.....	.....	.....	.....	8,645	15,590

Table of analyses of coal samples from mines in and near the Clintwood and Bucu quadrangles, Virginia—Contd.

Coal bed.	Name and location of mine.	Collector.	Laboratory No.	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.				Heating Value.		
						Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
Lower Banner ..	No. 55 of the Clinchfield Coal Corporation at Wilder, Va.	T. K. Harnsberger ..	18245	2.0	A	2.7	33.7	57.9	5.7	0.78	.....	.....	.....	7,920	14,280	
Do.	do.....	do.....	18246	2.0	B	.8	34.4	59.0	5.8	.80	.....	.....	.....	8,080	14,540	
					C	.....	34.7	59.5	5.8	.80	.....	.....	.....	8,145	14,600	
					D	.....	36.8	63.2	.....	.86	.....	.....	.....	8,650	15,570	
Upper Banner...	Graneest No. 1, of the Clinchfield Coal Corporation, about 1½ miles northwest of Toms Creek, Va.	T. K. Harnsberger ..	18226	1.5	A	2.4	33.4	59.4	4.8	.58	.....	.....	.....	8,035	14,460	
					B	.9	33.9	60.3	4.9	.59	.....	.....	.....	8,160	14,680	
					C	.....	34.2	60.9	4.9	.59	.....	.....	.....	8,235	14,830	
					D	.....	36.0	64.0	.....	.62	.....	.....	.....	8,600	15,500	
Do.	do.....	do.....	18227	1.5	A	2.3	32.9	59.9	4.9	.53	.....	.....	.....	8,035	14,460	
					B	.9	33.4	60.7	5.0	.54	.....	.....	.....	8,150	14,670	
					C	.....	33.7	61.3	5.0	.54	.....	.....	.....	8,225	14,810	
Do.	do.....	do.....	18228	1.4	A	2.3	32.7	59.2	5.8	.51	.....	.....	.....	7,965	14,370	
					B	.9	33.2	60.1	5.8	.52	.....	.....	.....	8,100	14,580	
					C	.....	33.5	60.6	5.9	.52	.....	.....	.....	8,170	14,710	
Do.	do.....	do.....	18229	1.5	A	.....	35.5	64.5	.....	.55	.....	.....	.....	8,685	15,630	
					B	2.3	32.9	59.6	5.83	.54	5.18	80.78	1.57	6.71	8,010	14,420
					C	.8	33.4	60.5	5.80	.55	5.09	81.97	1.59	5.50	8,130	14,630
Do.	Swansea mine of the Virginia Iron, Coal and Coke Company at Toms Creek, Va.	E. G. Woodruff	10386	1.5	A		33.7	61.0	5.84	.58	5.05	82.67	1.61	4.78	8,200	14,760
					B		35.5	64.5		.58	5.33	87.33	1.70	5.08	8,660	15,590
					C		35.5	64.5		.58	5.33	87.33	1.70	5.08	8,660	15,590
Do.	do.....	do.....	10386	1.5	A	2.5	31.7	60.3	5.51	.52	5.59	79.69	1.56	7.13	7,980	14,280
					B	1.0	32.2	61.2	5.59	.53	5.50	80.90	1.58	5.90	8,040	14,470
					C		32.5	61.8	5.65	.53	5.44	81.71	1.60	5.07	8,180	14,610
Do.	do.....	do.....	10386	1.5	A		34.5	65.5		.56	5.76	86.90	1.70	5.88	8,905	15,490
					B		34.5	65.5		.56	5.76	86.90	1.70	5.88	8,905	15,490
					C		34.5	65.5		.56	5.76	86.90	1.70	5.88	8,905	15,490

Table of analyses of coal samples from mines in and near the Clintwood and Bucu quadrangles, Virginia—Contd.

Coal bed.	Name and location of mine.	Collector.	Laboratory No.	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.				Heating Value.		
						Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
Upper Banner...	Cocburn mine of the Virginia Iron, Coal and Coke Company at Toms Creek, Va.	J. W. Groves and W. J. von Borries.	2221	1.6	A	2.7	32.4	60.4	4.5	0.52	...	...	...	...	8,080	14,540
					B	1.1	32.9	61.4	4.6	.53	...	...	...	...	8,210	14,780
					C	...	32.0	62.0	4.6	.53	...	...	...	...	8,305	14,960
					D	...	35.0	65.0	...	.56	...	...	...	...	8,705	15,070
Do.....	do.....	do.....	2222	1.7	A	2.9	32.0	61.0	4.1	.55	...	...	...	...	...	...
					B	1.2	32.6	62.0	4.2	.56	...	...	...	...	...	...
					C	...	33.0	62.8	4.2	.57	...	...	...	...	...	...
					D	...	34.4	65.6	...	.60	...	...	...	...	...	...
Do.....	No. 2 of the Clinchfield Coal Corporation, 1 1/4 miles northeast of Dante, Va.	T. K. Harnsberger..	18123	1.0	A	1.8	35.3	55.8	7.1	.58	...	...	...	...	7,800	14,040
					B	.8	36.7	53.8	7.2	.58	...	...	...	...	7,875	14,180
					C	...	36.9	53.6	7.3	.59	...	...	...	...	7,945	14,300
					D	...	38.8	61.2	...	.64	...	...	...	...	8,565	15,520
Do.....	do.....	do.....	18129	1.4	A	2.4	36.3	55.1	6.2	.52	...	...	...	...	7,840	14,110
					B	1.0	36.8	55.9	6.3	.53	...	...	...	...	7,945	14,300
					C	...	37.2	56.4	6.4	.53	...	...	...	...	8,025	14,450
					D	...	39.7	60.3	...	.57	...	...	...	...	8,570	15,530
Do.....	do.....	do.....	18130	0.8	A	1.6	36.7	55.3	6.4	.58	...	...	...	...	7,870	14,170
					B	.8	37.0	55.8	6.4	.58	...	...	...	...	7,935	14,300
					C	...	37.3	56.2	6.5	.59	...	...	...	...	8,000	14,400
					D	...	39.9	60.1	...	.63	...	...	...	...	8,550	15,380
Do.....	do.....	do.....	18131F	1.1	A	1.8	36.2	55.5	6.53	.54	5.25	79.28	1.49	6.91	7,830	14,100
					B	.8	36.5	56.1	6.00	.55	5.18	80.12	1.51	6.04	7,915	14,250
					C	...	36.8	56.5	6.65	.55	5.14	80.76	1.52	5.93	7,980	14,360
					D	...	39.4	60.6	...	.59	5.51	86.51	1.63	5.76	8,545	15,380
Do.....	do.....	P. M. Riefkin.....	10734	1.5	A	2.3	35.2	56.2	6.3	.59	...	...	...	...	7,830	14,100
					B	.8	35.7	57.1	6.4	.60	...	...	...	...	7,950	14,310
					C	...	36.1	57.5	6.4	.60	...	...	...	...	8,020	14,440
					D	...	38.6	61.4	...	.64	...	...	...	...	8,570	15,430

Table of analyses of coal samples from mines in and near the Clintwood and Bucu quadrangles, Virginia—Contd.

Coal bed.	Name and location of mine.	Collector.	Laboratory No.	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.				Heating Value.		
						Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
Upper Banner...	No. 2 of the Clinchfield Coal Corporation, 1½ miles northeast of Dante, Va.	P. M. Riefkin.....	10735	2.1	A	3.0	35.2	56.6	5.2	0.59	.....	.....	.....	7,880	14,150	
					B	.9	36.0	57.8	5.3	.60	.....	.....	.....	8,080	14,450	
					C	.....	36.2	58.4	5.4	.61	.....	.....	.....	8,100	14,590	
					D	.....	38.3	61.7	.....	.64	.....	.....	.....	8,560	15,410	
Do.....	do.....	do.....	10736	1.8	A	2.8	34.9	56.5	5.77	.59	5.32	80.13	1.43	6.76	7,890	14,150
					B	1.0	35.5	57.5	5.88	.60	5.21	81.60	1.46	5.25	8,005	14,410
					C	.....	36.0	58.1	5.93	.61	5.15	82.41	1.47	4.43	8,090	14,550
					D	.....	38.2	61.8	.....	.65	5.47	87.60	1.56	4.72	8,590	15,460
Do.....	No. 2 (called No. 3 when sampled) of the Clinchfield Coal Corporation at Dante, Va.	R. W. Stone.....	3942	1.3	A	2.4	32.4	57.9	7.3	.66	.....	.....	.....	.....	.....	.....
					B	1.1	32.8	58.7	7.4	.67	.....	.....	.....	.....	.....	.....
					C	.....	33.2	59.3	7.5	.68	.....	.....	.....	.....	.....	.....
					D	.....	35.9	64.1	.....	.74	.....	.....	.....	.....	.....	.....
Do.....	No. 5 of the Clinchfield Coal Corporation, 1½ miles north of Dante, Va.	P. M. Riefkin.....	10737	1.4	A	2.3	35.2	57.8	4.7	.55	.....	.....	.....	8,015	14,430	
					B	.9	35.7	58.6	4.8	.56	.....	.....	.....	8,130	14,690	
					C	.....	36.0	59.2	4.8	.56	.....	.....	.....	8,205	14,770	
					D	.....	37.8	62.2	.....	.59	.....	.....	.....	8,625	15,520	
Do.....	do.....	do.....	10738	1.2	A	2.1	35.1	57.1	5.7	.56	.....	.....	.....	7,930	14,290	
					B	.9	35.6	57.7	5.8	.57	.....	.....	.....	8,030	14,450	
					C	.....	35.9	58.3	5.8	.58	.....	.....	.....	8,100	14,590	
					D	.....	38.1	61.9	.....	.62	.....	.....	.....	8,600	15,480	
Do.....	do.....	do.....	10739	1.3	A	2.1	35.9	56.7	5.33	.57	5.45	80.24	1.43	6.98	7,945	14,330
					B	.8	36.4	57.4	5.40	.58	5.37	81.30	1.45	5.90	8,070	14,530
					C	.....	36.7	57.9	5.44	.58	5.33	81.93	1.46	5.26	8,130	14,640
					D	.....	38.8	61.2	.....	.61	5.64	86.64	1.54	5.75	8,600	15,490
Do.....	No. 3 of the Clinchfield Coal Corporation, 1 mile east of Dante, Va.	E. G. Woodruff.....	10887	1.4	A	2.3	35.7	55.0	7.00	.66	5.48	77.91	1.53	7.42	7,740	13,940
					B	.9	36.2	55.8	7.10	.67	5.40	79.02	1.55	6.26	7,850	14,130
					C	.....	36.5	56.3	7.16	.68	5.35	79.73	1.56	5.62	7,920	14,290
					D	.....	39.3	60.7	.....	.73	5.76	85.57	1.68	5.06	8,530	15,380

Table of analyses of coal samples from mines in and near the Clintwood and Bucu quadrangles, Virginia—(Contd.)

Coal bed.	Name and location of mine.	Collector.	Laboratory No.	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.				Heating Value.		
						Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
Upper Banner...	No. 6 of the Clinchfield Coal Corporation at Wilder, Va.	T. K. Harnsberger..	18235	2.4	A	3.3	35.7	55.0	6.0	0.55					7,760	13,970
					B	1.0	36.6	56.3	6.1	.56					7,945	14,310
					C		37.0	56.8	6.2	.57					8,080	14,450
					D		39.4	60.6		.61					8,555	15,400
Do.....	do.....	do.....	18236	2.4	A	3.2	35.4	55.1	6.3	.59					7,760	13,970
					B	.9	36.3	56.4	6.4	.60					7,945	14,300
					C		36.6	56.9	6.5	.61					8,080	14,430
					D		39.1	60.9		.65					8,575	15,440
Do.....	do.....	do.....	18237	2.4	A	3.3	35.1	55.9	4.7	.50					7,925	14,270
					B	.9	36.0	56.3	4.8	.51					8,115	14,610
					C		36.3	56.8	4.9	.52					8,195	14,750
					D		38.2	61.8		.55					8,615	15,510
Do.....	do.....	do.....	18238	2.4	A	3.3	35.1	55.9	5.71	.53	5.37	78.72	1.37	8.28	7,820	14,080
					B	1.0	35.9	57.2	5.86	.56	5.23	80.62	1.40	6.34	8,010	14,420
					C		36.3	57.8	5.91	.57	5.17	81.44	1.42	5.49	8,095	14,570
					D		38.5	61.5		.61	5.49	86.55	1.51	5.84	8,600	15,490
Splash Dam	Small local mine of O. C. Owens on Russell Frater Creek, 1 mile northeast of mouth.	do.....	17751	1.3	A	2.3	29.4	62.2	6.1	.76						
					B	1.0	29.7	63.0	6.2	.77						
					C		29.9	63.6	6.3	.78						
					D		31.6	67.9		.83						
Do.....	do.....	do.....	17752	1.6	A	2.5	29.2	63.2	5.1	.80						
					B	.9	29.7	64.2	5.2	.81						
					C		29.9	64.8	5.3	.82						
					D		31.6	68.4		.87						
Glamorgan.....	Glamorgan No. 3 of the Stone Gap Colliery Co. at Glamorgan, Va.	Chas. Butts.....	15100	1.6	A	2.6	33.1	59.3	5.0	1.37					7,895	14,220
					B	1.1	33.6	60.2	5.1	1.39					8,025	14,450
					C		34.0	60.9	5.1	1.41					8,115	14,600
					D		36.8	64.2		1.49					8,560	15,390

Table of analyses of coal samples from mines in and near the Clintwood and Bucu quadrangles, Virginia—Contd.

Coal bed.	Name and location of mine.	Collector.	Laboratory No.	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.				Heating Value.		
						Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
Glamorgan.....	Glamorgan No. 3 of the Stone Gap Colliery Co. at Glamorgan, Va.	Chas. Butts.....	15101	2.0	A B C D	3.2 1.3	31.8 31.9 32.3 32.3	59.1 60.3 61.1 65.4	6.37 6.50 6.58	0.87 0.89 0.90 0.96	5.27 5.15 5.08 5.44	78.02 78.61 80.65 86.33	1.65 1.68 1.71 1.83	7.82 6.17 5.08 5.44	7,730 7,885 8,550	13,910 14,200 14,380 15,360
Eagle.....	Small local mine of the Yellow Poplar Lumber Co., 3 miles east of the mouth of Pound River.	T. K. Harnsberger..	17743	1.7	A B C D	2.8 1.1	31.6 32.2 32.5 35.2	58.2 59.1 59.8 64.8	7.4 7.6 7.7	1.45 1.47 1.49 1.61	..... ..... ..... .....	..... ..... ..... .....	..... ..... ..... .....	..... ..... ..... .....	7,685 7,815 7,905 8,565	13,840 14,070 14,230 15,410
Do.....	do.....	do.....	17744	1.8	A B C D	3.0 1.2	32.4 33.0 33.4 35.7	58.4 59.5 60.2 64.3	6.2 6.3 6.4	1.62 1.65 1.67 1.78	..... ..... ..... .....	..... ..... ..... .....	..... ..... ..... .....	..... ..... ..... .....	7,795 7,865 8,030 8,575	14,030 14,200 14,400 15,440
Clintwood.....	Small local mine of Elbert Powers, on Big Ridge, 5½ miles south of Clintwood, Va.	W. A. Nelson.....	14767	3.3	A B C D	4.3 1.0	29.4 30.4 30.7 32.1	62.1 64.2 64.9 67.9	4.2 4.4 4.4	1.02 1.05 1.07 1.12	..... ..... ..... .....	..... ..... ..... .....	..... ..... ..... .....	..... ..... ..... .....	..... ..... ..... .....	..... ..... ..... .....
Do.....	Small local mine of John A. Yeates, 1 mile southwest of Clintwood, Va.	do.....	14768	1.2	A B C D	2.2 1.0	34.2 34.9 34.9 36.1	60.4 61.2 61.8 63.9	3.2 3.2 3.3	0.85 0.86 0.87 0.96	..... ..... ..... .....	..... ..... ..... .....	..... ..... ..... .....	..... ..... ..... .....	8,110 8,295 8,290 8,570	14,590 14,770 14,920 15,420
Do.....	Small local mine of Chase and Damon, ½ of a mile south of Clintwood, Va.	C. W. Dodge.....	3827	1.2	A B C D	2.2 1.0	30.1 30.5 30.8 32.1	63.7 64.5 65.1 67.9	4.0 4.0 4.1	0.87 0.88 0.89 0.93	..... ..... ..... .....	..... ..... ..... .....	..... ..... ..... .....	..... ..... ..... .....	..... ..... ..... .....	..... ..... ..... .....

Tests.

GENERAL STATEMENT.

Samples of coal, from two localities only a short distance south of the area described in this report, were subjected to a series of tests in fuel-testing plants of the U. S. Geological Survey to determine their value for commercial purposes. A run-of-mine sample from the Jawbone coal bed in the Virginia City No. 1 mine, at Virginia City, Va., was used in making steaming and producer-gas tests in the plant at Norfolk, Va. It had been exposed to weathering for 36 days before use at the testing plant. A car sample, over a 3½-inch bar screen, from the Upper Banner coal bed in the Coeburn mine of the Virginia Iron, Coal, and Coke Company, at Toms Creek, Va., was tested in the St. Louis plant.

In the following tables the essential results of these tests are summarized in a manner intended to show briefly the adaptability of the coal to the uses for which it was tested. Further information regarding the types of testing apparatus used, conditions under which the tests were made, etc., may be had by referring to the publications cited in the footnotes.

The tests emphasize the excellent qualities of coal that is essentially the same as that in the Clintwood and Bucu quadrangles. The coking tests gave especially favorable results, as did also private coking tests made of coal from the Clintwood bed at the Beverly mine, near Clintwood. The Pishel field test for coking coal was applied to coal from many places in the two quadrangles and indicated excellent coking qualities in all but two trials. Commercial operations have proved that high-grade coke can be made from the Upper Banner bed in the southwest corner of the Clintwood quadrangle, and there is no reason to suppose that any of the coal in the region is not suitable for the same purpose.

STEAMING TESTS.¹

Test No. 601, Jawbone coal.—The coal burned with a medium-length flame and caked. A porous clinker formed on the dead plate and adhered

¹ Burrows, J. S., Mine sampling and chemical analyses of coals: U. S. Geol. Survey Bull. 362, p. 9, 1907.

Breckenridge, L. P., Preliminary report on the operations of the fuel-testing plant of the United States Geological Survey at St. Louis, Mo., 1905: U. S. Geol. Survey Bull. 290, pp. 194-195, 1906.

Breckenridge, L. P., Kreisinger, Henry, and Ray, W. T., Steaming tests of coals and related investigations: Bureau of Mines Bull. 23, 1912.

to the bridge wall. Size of coal as used not recorded. Duration of test, 8 hours. Kind of grate, underfeed.

Test No. 602, Jawbone coal.—The coal burned with a medium-length flame and caked. A small porous clinker formed on the dead plate and adhered to the bridge wall. Size of coal as used not recorded. Duration of test, 8.10 hours. Kind of grate, underfeed.

Test No. 280, Upper Banner coal.—Automatic air admission not operated; clinker and refuse easily removed from furnace. Size of coal as used: Over 1-inch, 44.7 per cent; $\frac{1}{2}$ -inch to 1-inch, 20.2 per cent; $\frac{1}{4}$ -inch to $\frac{1}{2}$ -inch, 15.7 per cent; under $\frac{1}{4}$ -inch, 19.4 per cent. Duration of test, 9.88 hours. Kind of grate, rocking.

Test No. 283, Upper Banner coal.—Automatic air admission was operated. A thin solid clinker adhered to the grate. Size of coal as used: Over 1-inch, 32.8 per cent; $\frac{1}{2}$ -inch to 1-inch, 16.5 per cent; $\frac{1}{4}$ -inch to $\frac{1}{2}$ -inch, 15.6 per cent; under $\frac{1}{4}$ -inch, 35.1 per cent. Duration of test, 10 hours. Kind of grate, rocking.

Proximate analyses of coal as used.

	Test 601.	Test 602.	Test 280.	Test 283.
Moisture	1.3	1.6	1.7	3.3
Volatile matter	28.7	28.7	33.3	32.0
Fixed carbon.....	54.8	53.1	60.3	60.2
Ash	15.7	16.6	4.7	4.5
Sulphur	.94	.94	.64	.56

Ultimate analyses figured on moisture-free basis.

	Test 601.	Test 602.	Test 280.	Test 283.
Carbon	71.14	70.59	82.80	82.95
Hydrogen	4.52	4.47	4.98	4.98
Oxygen	6.21	5.69	5.18	5.19
Nitrogen	1.25	1.22	1.64	1.64
Sulphur	.95	1.16	.65	.58
Ash	15.93	16.87	4.75	4.66

Summary of steaming tests.

	Test 601.	Test 602.	Test 280.	Test 283.
Heating value of coal B. t. u. per lb. dry coal.	12,911	12,607	14,908	14,936
Force of draft:				
Under stack damper.....inch water....	0.39	0.35	0.42	0.37
Above fire .....do.....	.31	.23	.15	.16
Furnace temperature .....°F.....	2,336	.....	2,452	2,537
Dry coal used per square foot of grate surface per hour .....pounds....	18.14	21.88	16.40	16.47
Equivalent water evaporated per square foot of water-heating surface per hour .....pounds....	3.28	3.69	2.91	2.99
Water apparently evaporated per pound of coal as fired.....pounds....	7.70	7.07	8.14	8.18
Water evaporated from and at 212° F.:				
Per pound of coal as fired.....pounds....	8.94	8.32	9.74	9.79
Per pound of dry coal .....do.....	9.06	8.46	9.91	10.12
Per pound of combustible.....do.....	10.97	10.36	10.66	10.84
Efficiency of boiler, including grate, per cent	67.77	64.80	64.19	65.43
Boiler horse-power:				
Builder's rating	210	210	210	210
Developed on test.....	193.0	217.4	171.4	175.9
Analysis of ash:				
Carbon	9.93	11.26	27.88	34.47
Earthy matter	90.07	88.74	72.12	65.53

PRODUCER-GAS TESTS.¹

✓ *Test No. 163, Jawbone coal.*—As used, $\frac{1}{2}$ to $\frac{2}{3}$ slack. Failure of water supply made it impossible to carry this test beyond 8 hours, a period so short that the accuracy of the results is doubtful. Average B. t. u. of gas per cubic foot, about 149.

Test No. 75, Upper Banner coal.—Size as used: Over 1-inch, 51 per cent; $\frac{1}{2}$ -inch to 1-inch, 14 per cent; $\frac{1}{4}$ -inch to $\frac{1}{2}$ -inch, 13 per cent; under $\frac{1}{4}$ -inch, 22 per cent. Duration of test, 50 hours. Average B. t. u. of gas per cubic foot, 156.

¹ Burrows, J. S., Mine sampling and chemical analysis of coals: U. S. Geol. Survey Bull. 362, p. 9, 1908.

Fernald, R. H., Preliminary report on the operation of the fuel-testing plant of the United States Geological Survey at St. Louis, Mo., 1905: U. S. Geol. Survey Bull. 290, pp. 193-195, 1906.

Fernald, R. H., and Smith, C. D., Résumé of producer-gas investigations: Bureau of Mines Bull. 13, 1911.

Proximate analyses of coal as fired.

	Test 163.	Test 75.
Moisture	1.3	1.6
Volatile matter	29.7	31.7
Fixed carbon	53.6	61.8
Ash	15.4	4.9
Sulphur	1.14	.49

Analyses of gas (per cent by volume).

	Test 163.	Test 75.
Carbon dioxide (CO ₂)	9.7	9.7
Carbon monoxide (CO)	19.7	19.3
Hydrogen (H ₂)	14.5	13.8
Methane (CH ₄)	2.3	3.1
Nitrogen (N ₂)	53.8	54.1

Summary of producer-gas tests.

	Test 163.			Test 75.		
	Coal as fired.	Dry coal	Combustible.	Coal as fired.	Dry coal	Combustible.
Coal used in producer (pounds per horse-power per hour).						
Per electrical horse-power:						
Available for outside purposes	1.23	1.22	1.03	1.21	1.18	1.13
Developed at switch board	1.20	1.19	1.00	1.13	1.11	1.06
Per brake horse-power:						
Available for outside purposes	1.05	1.04	.87	1.03	1.01	.96
Developed at engine	1.02	1.01	.85	.96	.95	.90
Coal used by producer plant, including fuel equivalent of auxiliary power (pounds per horse-power per hour).						
Per electrical horse-power:						
Available for outside purposes	1.52	1.50	1.26	1.29	1.27	1.21
Developed at switch board	1.48	1.46	1.23	1.21	1.19	1.13
Per brake horse-power:						
Available for outside purposes	1.29	1.28	1.07	1.10	1.08	1.03
Developed at engine	1.26	1.24	1.05	1.03	1.01	.96

COKING TESTS.¹

Two tests, Nos. 61 and 88, were made of the Upper Banner coal from Toms Creek, Va., to determine its coking properties. In test 61 the coal was finely crushed; in test 88 it was as shipped (over 3½-inch bar screen).

Summary of coking tests.

	Test 61.	Test 88.
Duration of test.....hours.....	45	50
Specific gravity, real.....	1.93	1.87
Specific gravity, apparent.....	1.25	1.12
Weight per cubic foot, dry.....pounds.....	77.72	69.30
Weight per cubic foot, as received (wet).....do.....	99.67	94.26
Percentage coke.....	65.00	60.00
Percentage cells.....	35.00	40.00
Six-foot drop test, percentage over 2-inch mesh:		
1.....	92.00	93.50
2.....	85.00	89.00
3.....	78.50	83.50
4.....	75.00	80.50
Weight of coal.....pounds.....	12,000	12,000
Weight of coke.....do.....	8,160	7,907
Weight of breeze.....do.....	240	336
Percentage coke.....	68.00	65.89
Percentage breeze.....	2.00	2.80
Total percentage yield.....	70.00	68.69

The analysis of a typical 72-hour Connellsville coke is shown in the following table as a standard for comparison. Judged by the analyses, coke made from the Upper Banner coal is as good as that from the Connellsville district.

Analysis of coal as used and resulting coke.

	Connells- vills coke.	Test 61.		Test 88.	
		Coal.	Coke.	Coal.	Coke.
Moisture.....	.18	2.87	0.29	2.49	0.16
Volatile matter.....	.32	31.58	1.21	31.90	1.26
Fixed carbon.....	88.75	61.43	92.60	61.16	91.85
Ash.....	10.75	4.12	5.90	4.45	6.73
Sulphur in coke.....	.87	.56	.61	.57	.55
Sulphur in ash.....	.033		.085		.070
Phosphorus.....	.018		.001		.006
Specific gravity.....	1.92		1.93		1.87

¹ Belden, A. W., Preliminary report on the operations of the fuel-testing plant of the United States Geological Survey at St. Louis, Mo., 1905: U. S. Geol. Survey Bull. 290, pp. 193-196, 1906.

Belden, A. W., Washing and coking tests of coal and cupola tests of coke: U. S. Geol. Survey Bull. 336, 1908.

Test 61, remarks.—Coke of light gray and silvery color; much deposited carbon; metallic ring; cell structure small; breakage good; long, large, heavy pieces; very heavy coke.

Test 88, remarks.—Coke of light gray and silvery color; much deposited carbon; metallic ring; cell structure small; breakage good; good heavy coke; decreased yield of coke and increased amount of breeze probably due to fact that coal was not crushed.

CUPOLA TESTS OF COKE.¹

Each of the two samples of coke, made from the Upper Banner coal from Toms Creek, Va., was subjected to two cupola tests, the results of which are shown in the following table. The results of a typical test of Connellsville 72-hour coke are given in the first column, to furnish a standard for comparison.

¹ Moldenke, Richard, Washing and coking tests of coal and cupola tests of coke: U. S. Geol. Survey Bull. 336, 1908.

Summary of cupola tests.

	Connellsville Coke.		Coke test 61.		Coke test 66.		Weight and time of each ladle—(Contd.)—	Coke test 61.		Coke test 66.	
	Test 19.	Test 33.	Test 91.	Test 98.	Test 40.	Test 40.		Test 33.	Test 91.	Test 58.	Test 40.
<i>Charges (Pounds)</i> —											
1 Coke bed.....	220	290	250	290	340	340	6 lbs.	84	110	64	75
2 Pig iron.....	660	660	780	750	730	730	at	4.23	3.61%	10.54	11.88%
3 Scrap.....	230	230	250	250	240	240	7 lbs.	73	181	10.64	11.88%
4 Coke.....	53	50	45	45	45	45	at	4.24	3.62	10.54%	11.88%
5 Pig iron.....	388	380	375	375	353	353	8 lbs.	71	94	88	55
6 Scrap.....	133	130	135	135	128	128	at	11.32	3.64	10.55	11.41
7 Coke.....	33	50	45	45	45	45	9 lbs.	305	113	62	92
8 Pig iron.....	346	360	375	375	353	353	at	4.25%	3.64%	10.55	11.41%
9 Scrap.....	133	130	135	135	128	128	10 lbs.	135	80	99	75
10 Coke.....	52	50	45	45	47	47	at	11.36	3.65	10.56%	11.43
11 Pig iron.....	397	380	375	375	353	353	11 lbs.	60	90	70	88
12 Scrap.....	133	130	135	135	128	128	at	4.26	3.66	10.57	11.44
13 Coke.....	52	50	45	45	47	47	12 lbs.	123	63	99	75
14 Pig iron.....	397	380	375	375	353	353	at	11.38	3.66%	10.58	11.44%
15 Scrap.....	133	130	135	135	128	128	13 lbs.	170	66	182	91
<i>Totals (Pounds)</i>	430	430	430	430	480	480	14 lbs.	11.40	3.67	10.59%	11.45
Coke.....	2,370	2,370	2,370	2,350	2,250	2,250	15 lbs.	11.40	3.68%	10.60	11.45
Pig iron.....	750	750	750	750	750	750	at	51	80	160	75
Scrap.....	7	7	7	7	7	7	16 lbs.	4.84	3.69	11.05%	11.46%
Ratio of iron to coke.....	7%	7%	7%	7%	7%	7%	17 lbs.	4.85	4.01	11.01	11.46
Maximum blast pressure (oz.).....	3,470	1,584	3,432	1,710	1,701	1,701	18 lbs.	4.86	4.01	11.01	11.46
Iron poured (lbs.).....	3,470	2,307	2,307	2,300	2,071	2,071	at	4.87	4.01%	11.02%	11.46%
Iron melted (lbs.).....	3,470	2,307	2,307	2,300	2,071	2,071	19 lbs.	4.88	4.02	11.03	11.47
(lbs. recovered).....	3,470	2,307	2,307	2,300	2,071	2,071	20 lbs.	4.89	4.03	11.04	11.48
(lbs. recovered) (lbs.).....	3,470	2,307	2,307	2,300	2,071	2,071	21 lbs.	4.90	4.04	11.05	11.49
Melting ratio (per cent.).....	3.3	11.80	3.30	5.45	8.30	8.30	22 lbs.	4.91	4.05	11.06	11.50
Melting ratio (lbs. to coke).....	6.03	7.00	7.33	6.75	6.43	6.43	23 lbs.	4.92	4.06	11.07	11.51
Melting ratio (lbs. per hour).....	5,480	4,947	5,023	4,931	4,154	4,154	24 lbs.	4.93	4.07	11.08	11.52
Blast on at.....	10.57	4.03	3.30	10.33	11.14	11.14	25 lbs.	4.94	4.08	11.09	11.53
Iron running.....	A.M.	P.M.	P.M.	A.M.	A.M.	A.M.	26 lbs.	4.95	4.09	11.10	11.54
Weight and time of each ladle.....	11.08	4.12	3.37	10.35	11.35	11.35	27 lbs.	4.96	4.10	11.11	11.55
1 lbs.	175	85	133	103	64	64	28 lbs.	4.97	4.11	11.12	11.56
2 lbs.	11.07	4.13	3.45	10.45	11.37	11.37	29 lbs.	4.98	4.12	11.13	11.57
3 lbs.	11.15	105	104	107	68	68	30 lbs.	4.99	4.13	11.14	11.58
4 lbs.	11.11	4.19	3.45%	10.45%	11.30	11.30	31 lbs.	5.00	4.14	11.15	11.59
5 lbs.	11.13	5.04	111	77	80	80	32 lbs.	5.01	4.15	11.16	11.60
6 lbs.	11.13	4.30	3.47	10.50%	11.31	11.31	33 lbs.	5.02	4.16	11.17	11.61
7 lbs.	11.10	5.04	135	74	68	68	34 lbs.	5.03	4.17	11.18	11.62
8 lbs.	11.14	4.31	3.47%	10.51	11.32	11.32	35 lbs.	5.04	4.18	11.19	11.63
9 lbs.	11.14	5.04	84	84	73	73	36 lbs.	5.05	4.19	11.20	11.64
10 lbs.	11.16	4.32	3.51	10.51%	11.33	11.33	37 lbs.	5.06	4.20	11.21	11.65

Remarks: Test 19. Iron hot. Test 33. Iron hot and fluid; melting too fast to handle; blast off 4 minutes. Test 91. Iron hot. Test 58. Iron hot; blast off 5 minutes. Test 40. Temperature of iron medium.

SUMMARY.

An examination of the analyses and tests described in the preceding pages leads to very favorable conclusions as to the purity and value of the coals themselves. The practical features and the essential working qualities of the fuels, as indicated in a limited number of steaming, coking, briquetting, producer, and foundry tests have already been quoted from the official records of the tests. These tests, which are not so numerous as is to be desired, were not in all cases conducted under favorable circumstances or with coal from the best deposits, and the results, gratifying as they may be, probably do not do more than justice to either the samples submitted or the region as a whole.

Information as to the chemical composition, which discloses the purity of the coals, and as to the calorific values, i. e., the heating power of the coals as determined by standard calorimetric methods in the laboratory, is given in the accompanying table of analyses. This table, though not so large as is desirable, contains the results of the analysis and calorific testing of enough cuttings taken from coal beds in widely different parts of the region to entitle it to confidence as approximately representative of the coals of the quadrangles. In fact, it must be noted that the samples from the Splash Dam, the Eagle, and the Clintwood beds, and some of those from the Kennedy, were taken from small local or country mines and therefore may not show either the full rank or the real heat value of the fuels. The proportions of the elements in the organic matter are in some cases given in the form of ultimate analyses.

From an inspection of the analyses, it will be seen that the coals are of high bituminous rank with very low moisture content; with a percentage of fixed carbon in general approximating 60 per cent^{*}; with relatively low ash, and with an exceptionally small content of sulphur. In other words, the coals are notably pure. The averages of the moisture, of the ash, the sulphur, and the B. t. u.'s in the samples "as received" (line A) for all the beds except the Jawbone are indicated in the following synopsis:

^{*} The percentage in Sample No. 22346, cut in the Jackson bank, 3 miles northwest of Honaker, probably does not represent the fixed carbon of the normal unweathered coal.

Averages of analyses for each coal.

Name of Coal and number of samples.	Moisture.	Fixed Carbon.	Ash.	Sulphur.	B. t. u.'s.
Tiller (4) A	2.2	59.4	6.5	.48	14,100
..... D		65.0			15,500
Kennedy (7) A	2.9	59.6	6.98	.98	13,750
..... D		67.1			15,500
Lower Banner (9) A	2.5	57.0	6.17	.75	14,150
..... D		62.5			15,500
Upper Banner (23) A	2.5	57.3	5.7	.56	14,200
..... D		62.4			15,500
Splash Dam (2) A	2.4	62.7	5.6	.78	
..... D		68.2			
Glamorgan (2) A	2.9	59.2	5.7	1.12	• 14,050
..... D		64.8			15,400
Eagle (2) A	2.9	58.3	6.8	1.54	13,950
..... D		64.6			15,450
Clintwood (3) A	2.9	62.1	3.8	.91	14,600
..... D		66.6			15,400
Averages of above coals.... A	2.6	59.5	5.9	.89	14,150
..... D		65.2			15,450

In line D is shown the corresponding averages of the fixed carbon and British thermal units (B. t. u.'s) on what is sometimes known as the "pure coal basis." This form of representation, which is theoretical and should be used only in the comparative study of the qualities and ranks of coals, is obtained by excluding the moisture, ash, and sulphur from the proximate analysis and recalculating the volatile matter and fixed carbon to total 100 per cent. These percentages should not be employed to describe coals as commercially produced or sold.

The high qualities of most of the coals appear even in the cuttings from small local mines. Those of the Eagle bed, while inferior to some others, are, nevertheless, worthy of comparison with the coals of other regions. The Clintwood is exceptionally pure, and the Kennedy is relatively high in ash only southwest of Russell Fork, where it has been crushed by shearing movements. The three samples from the Jawbone bed are conspicuous among the other coals of the region for their high ash and high moisture. In fact, this coal is well recognized to be relatively impure and inferior at most points at which it has been examined. Hence it will be eliminated from further discussion, though it is but little inferior to many of the competing coals from other fields.

For the purposes of comparison of the coals from other regions and fields of the United States, comprehensive and generally representative

analyses will be found in great numbers in Bulletins 22 and 85 of the Bureau of Mines. To these reports the reader is referred for data concerned in the following discussion.

The examination of the analyses of coals from the Clintwood and Bucu quadrangles presented in the foregoing tables, and a comparison of the same with those representing the principal mining districts of West Virginia, make it evident that the coals of the region studied are equal to the highest rank of the Kanawha coals of southern West Virginia, namely, those along the easternmost border of the Kanawha field, or, in other words, those in a rather narrow zone along the border of the Pocahontas and New River coal fields. They are apparently slightly higher in rank than the coals in the region immediately northwest of Pine Mountain, though neither this difference nor its effects are well marked. Farther west, both in Kentucky and West Virginia, the coals fall off in rank and calorific value and in most areas are more impure. On the whole, the coals of the quadrangles here described present a marked advantage over the latter as to ash and sulphur content.

The Pocahontas and New River coals are distinctly above the coals of this part of the Virginia region as to rank, being 5 to 15 per cent higher in fixed carbon, and are in general their equal in ash and sulphur, while, as is to be expected, their more advanced rank gives them notably greater B. t. u. values. Also, the New River and Pocahontas coals are coked with less loss of volatile matter. On the other hand, for household use and for export to markets intolerant of great quantities of slack or fine coal, most of the Virginia coals, which have not been so crushed and made friable by the dynamic forces that gave the Pocahontas and New River coals their higher rank, have a distinct advantage on account of the larger proportion of lump coal which may even permit grading by sizes with smaller waste in dust or slack. The Virginia coal especially commends itself as a reasonably high rank, high heat value, low ash, and low sulphur lump coal for export, as well as for domestic use.

In the Tennessee coal field there are several localities where, on account of the higher rank, as shown by the more advanced elimination of volatile matter, the coals have as great calorific value as those in question, though the ash and sulphur content are higher. Generally the coals of the same rank contain larger proportions of sulphur to which is usually added a higher ash. In the areas of extraordinarily low ash coals, like Campbell and Claiborne counties in Tennessee, the rank of the coals is so low as to give them a calorific value perceptibly under that of the Virginia coals, in which, moreover, the sulphur is nearly everywhere smaller in amount.

The coals of Alabama vary greatly in quality. At some localities the fuel is clearly of higher rank and heating power than that of the Virginia area, though nearly everywhere higher sulphur is found in the former. On the whole, however, higher ash also seems to mark the Alabama coal field, the greater part of which is inferior also as to the rank and calorific value of its fuels.

As compared with the Oklahoma coal field as a whole the Virginia coal possesses marked advantages in rank, purity, and heat value. Even toward the eastern border of the Oklahoma field, in which direction the rank of the coals rises above that of the Virginia fuel, the consequent calorific advantage is at most points neutralized by higher ash and sulphur. On the other hand, most of the Oklahoma localities showing lower ash have coals of rank so much lower as to make them of lower calorific value also. Passing eastward into Arkansas, the Paleozoic coals are all of higher rank; but except at a few points in the semibituminous area, the greater ash and sulphur contents seem to give them inferior heat values. It remains to be seen whether in an export trade the friability of the purest of the Arkansas semibituminous coal will offset its advantages in rank and heat value.

As compared with the coals of the other Mississippi Valley States, including Illinois, Indiana and the western Kentucky coal field, the Virginia coals are distinctly superior, being of considerably higher rank, generally lower in ash, almost everywhere lower in sulphur, and much higher in calorific value. The differences in the latter, which often exceed 2,000 B. t. u.'s in favor of the Virginia coal, will possibly be found, in some foreign market that is partial to lump coal, to be pitted against the larger percentages of cubical and stronger lump in the coals of the upper Mississippi valley.

The coals of Ohio are so much lower in fixed carbon, i. e., in rank, as hardly to equal the Virginia coals in heat value even where the former are at their best. In most cases they are higher in sulphur and in ash.

Although the coals of the Potomac and Georges Creek-Frostburg basins in western Maryland are clearly much higher in rank, they are in many places lower in heat value, probably on account of the higher ash and sulphur. However, in the southern part of the Potomac basin and the neighboring region of West Virginia, the coals appear to be purer and with higher values, and are at some locations clearly superior to the Clintwood-Bucu coals. In these high-rank coals there is, again, a larger proportion of fine coal or slack in the run-of-mine product. The same is true of the high-grade coals of the so-called "Clearfield region" of Clearfield, Cambria,

Blair, and Somerset counties in Pennsylvania, particularly the Windber district. Nevertheless, it is interesting to note that with respect to moisture and sulphur, and, in many cases, to ash, the Virginia coals compare advantageously, though they are not nearly so high in rank and in calorific value.

In the northern Appalachian region the Virginia coals concerned in this study seem to find closest comparisons in the low ash and low sulphur coals of the Fairmont district in northern West Virginia and in the Uniontown-Connellsville zone of Pennsylvania. With these coals the average beds of the Clintwood and Bucu regions are comparable in rank as well as in efficiency, ash, and sulphur, slightly lower sulphur being generally found in the latter area. The low ash, low moisture, and abnormally low sulphur in the Virginia area give these coals an advantage over those farther west in northern West Virginia and in Pennsylvania, toward the western borders of which the lower fixed carbon is attended in general with lower calorific values.

The comparability in rank and other features between the coals of the southwestern Virginia region and the coals of the Uniontown-Connellsville region of Pennsylvania has just been pointed out in the preceding paragraph. Also it will have been noted in the accounts of coking tests that for coking and furnace use coals from these two regions are closely comparable and apparently nearly equal. From the single test made at the experimental plant formerly conducted by the United States Geological Survey, it would seem that the coke made from the Connellsville coal was slightly higher in sulphur than that from the Upper Banner coal of southwestern Virginia. Further tests should precede final conclusions as to the relative merits of these coals for coking. Both the Virginia and Connellsville regions are similar as to the rather large amount of volatile matter, about 35 per cent, pure coal basis, in the beds, the coking of which entails a great and lamentable waste unless by-product ovens are used. This waste should be prevented whenever and wherever possible. The coal from the Toms Creek mines has been coked for more than twenty years.

The samples, analyses of which are presented in the foregoing tables, contain promise of a fuel output of great purity and value. In fact, the expectation seems fully justified that there will be developed in the Clintwood-Bucu region many mines in which the coal will contain about 60 per cent fixed carbon; will run under 2.6 per cent of moisture, 6 per cent of ash, .9 per cent of sulphur; and will contain over 14,200 B. t. u.'s as it is loaded in the cars. Most of this will make a good coke.

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LEGEND:

Wash Formation
 (Symbol: wavy lines)
 This formation is composed of...
 (Symbol: horizontal lines)
 This formation is composed of...
 (Symbol: vertical lines)
 This formation is composed of...

Cladville Sandstone
 (Symbol: horizontal lines)
 This formation is composed of...
 (Symbol: vertical lines)
 This formation is composed of...

Norton Formation
 (Symbol: diagonal lines)
 This formation is composed of...
 (Symbol: horizontal lines)
 This formation is composed of...
 (Symbol: vertical lines)
 This formation is composed of...

Lee Formation
 (Symbol: cross-hatch)
 This formation is composed of...
 (Symbol: horizontal lines)
 This formation is composed of...
 (Symbol: vertical lines)
 This formation is composed of...

Unidentified
 (Symbol: diagonal lines)
 This formation is composed of...
 (Symbol: horizontal lines)
 This formation is composed of...
 (Symbol: vertical lines)
 This formation is composed of...

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VIRGINIA GEOLOGICAL SURVEY
UNIVERSITY OF VIRGINIA

THOMAS LEONARD WATSON, PH. D.
DIRECTOR

Bulletin No. XIII

The Clays of the Piedmont Province, Virginia

BY

H. RIES AND R. E. SOMERS

CHARLOTTESVILLE
UNIVERSITY OF VIRGINIA
1917

CS



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LETTER OF TRANSMITTAL

VIRGINIA GEOLOGICAL SURVEY,
UNIVERSITY OF VIRGINIA,
CHARLOTTESVILLE, APRIL 1, 1917.

Governor Henry C. Stuart, Chairman, and Members of the State Geological Commission:

GENTLEMEN:—I have the honor to transmit to you herewith, and to recommend for publication as Bulletin No. XIII of the Virginia Geological Survey Series of Reports, a manuscript and illustrations of a report on "The Clays of the Piedmont Province, Virginia," by Professors Ries and Somers.

The clays of the Piedmont province are abundant, but at present they are developed to only a comparatively small extent. This bulletin, prepared to meet an urgent demand for accurate information on the clay resources of this province, should aid in the greater development and utilization of the clays.

Respectfully submitted,

THOMAS L. WATSON,
Director.

THE CLAYS OF THE PIEDMONT PROVINCE, VIRGINIA

By H. RIES AND R. E. SOMERS.

INTRODUCTION.

The field work for this report was carried on during the season of 1915, and the laboratory tests during the following winter. In the course of the work an effort was made to visit all parts of the Piedmont region, which were located within a sufficient distance from the railroad to permit any clay deposits they contained being worked.

Samples for testing were collected not only from the different geological formations, but, where these were of considerable extent, samples were obtained from the same formation at a number of different points. These samples were of two sizes, namely, large and small.

The large samples were taken chiefly from those localities which were specially well located for establishing a plant, or where the outcrops were large. The small samples were taken in part from less important localities, and to obtain a clue regarding the nature of the clay from a given formation at points other than those supplying the large samples.

TESTING THE CLAYS.

To the practical clay worker, the physical characteristics of the clay are of prime importance, the chemical analysis being of little or no value. It was consequently the former class of properties that were investigated. All samples were carefully taken, so as to represent the average of the deposit, and not a selected sample.

The clays so obtained were put through a crusher with $\frac{1}{8}$ -inch opening, so as to break up the stony fragments, and the ground material was then mixed with water to a plastic mass. From this bricklets were molded by hand, and these were used to determine the average air shrinkage. The same bricklets were then slowly fired to cones^a 010, 05, 03, and 1, or higher

^aCones or Seger Cones are a series of artificial mixtures, molded into slender pyramids. The series range from 022 to 01, then 1 up to 39. The first named has the lowest fusion point, and the last named the highest. The theoretic fusion points of successive numbers differ by 20° C. Thus 010 used in this report fuses at 950° C; 05 at 1050° C; 03 at 1090° C; and 1 at 1150° C. As the temperature approaches the fusion point of the cone the latter begins to soften and bends over until the tip touches the base, when the fusion point is supposed to have been reached. The cones are not however used for temperature measurements, but for determining pyro-chemical effects. Thus, if a certain clay develops a body of the proper quality at say Cone 1, this number cone can be placed in the kiln to be used as a gauge of the firing process.

if necessary, and the fire shrinkage, absorption, and color, after burning, determined on them.

Another lot of the mixed plastic clay was molded into briquets. These were first dried slowly in the air, and then in a hot-air bath, after which they were tested to determine their tensile strength. As some doubt exists regarding this last-mentioned test, a word of explanation should be given.

The tensile strength expresses the resistance of the air-dried clay to rupture. A clay of good tensile strength will stand handling in its unburned condition better than one of low tensile strength. Moreover, this property conveys to us an idea of the clay's bonding power. On the other hand, it is not a direct measure of the plasticity as some believe, nor does it indicate the probable strength of the clay after burning. Another fact brought out by these tests is that a clay may have a very low tensile strength, and yet flow smoothly through the die of a stiff-mud machine. The individual briquets sometimes show considerable variation in strength, and it has been suggested that this might be decreased by adding a certain amount of a standard sand. This, of course, may decrease the average tensile strength of the clay, and so for purposes of comparison all clays to be compared should be treated in the same way.

Still another lot of the large samples collected was put through a small power-driven stiff-mud machine, and the results are given in the tests. If the clay worked well in the brick die, it was also tried in the hollow block, and other dies.

While the stiff-mud tests can be regarded as giving clues to the workability of the clay by this process, their failure in some cases is not necessarily to be regarded as decisive, for the reason that almost every clay in stiff-mud work is a problem by itself; and, while it may not work well in one type of die, it often does in another.

Another lot of the clay was dry-ground to pass through a 20-mesh sieve, and molded in a hand-power dry-press machine. Most of the Piedmont clays failed here, because of their grittiness.

The kaolins were burned not only in their crude condition, but were also put through a washing test to eliminate the grit, and the washed product fired at the proper temperature.

ORIGIN OF THE PIEDMONT CLAYS.

The clays of the Piedmont region fall into three classes, namely, (1) residual, (2) colluvial, and (3) transported.

RESIDUAL CLAYS.

These are derived from all rocks by weathering processes. As a result rocks like granites, gneisses, and schists are broken down to a clayey mass—the residual clay. Since the weathering agents begin their attacks on the surface, and work from there into the rock mass, the decomposition is most complete above, and gradually diminishes downward until fresh, undecomposed rock is reached. We therefore often find that at the surface, and extending downward for a variable depth, the rock may be so completely decomposed that little of the original structure remains. This may grade downward into a second poorly-defined zone in which the material is pretty well weathered, but the rock structure is still retained. Below this there may be a third zone, partly decomposed, and containing some partly-decayed rock fragments, which in turn grades into the solid rock.

The depth of these several zones may vary, and each one is not always present. The clay of the upper zone is usually the most plastic,^a while that of the second may be noticeably less so. This is an important feature to recognize, because the upper zone alone may not be deep enough to work, and so in taking a sample it is necessary if possible to include some of the lower-lying material.

Residual clays vary greatly in depth, and even within a short distance may show great irregularity in thickness, this variation being due to unevenness of either the land surface or the bed rock.

Variation in depth may be due to variation in depth of weathering or erosion. On a flat surface the residual clay is likely to accumulate, as it is not washed away, while on a slope or ridge crest where the rain wash removes the soil rapidly, unless protected by vegetation, the products of weathering are apt to be removed. Bearing these facts in mind, we can see the necessity of carefully determining the extent and depth of a deposit of residual clay.

Most residual clays are colored yellow, brown, or red by iron oxide, which is supplied by the decomposition of iron-bearing silicates like biotite mica,

^aTillage of residual clay sometimes loosens the upper few inches so that the surface water washes out the clay particles. The surface soil may therefore appear sandy or loamy, but be immediately underlain by the sticky clay of the upper zone.

hornblende, etc. If these minerals are absent the clay is white or nearly so. The ferruginous residuals burn red or brown, while the whitish ones usually burn white or light buff.

The crystalline rocks from which most of the Piedmont residual clays are derived often contain veins of quartz, which in weathering do little more than break up into angular fragments. These remain scattered through the clay, and must be crushed or screened out before the material can be put through the molding machine.

COLLUVIAL CLAYS.

In many localities, the residual clays formed on hillsides are moved a comparatively short distance down slope, the action being partly a sliding of the deposit down hill, and partly a wash process. Such deposits are termed *colluvial*.

TRANSPORTED CLAYS.

As residual clays are washed down the slopes of the land they reach the streams, and are carried along by the current, until it slackens enough to deposit them. The clay so deposited is called a *transported* or *sedimentary* clay. We may therefore get several types of transported clay, depending on the conditions of deposition.

FLOOD PLAIN CLAYS.

These represent a common type in the Piedmont region. They include the clayey sediment deposited by streams on the flat tracts (flood plains) which often border the river courses. Many of the streams flowing across the Piedmont belt are bordered by flood-plain terraces underlain by clay.

These clays are rather characteristic in their occurrence. They vary from plastic to sandy, and the clay may grade into sand both vertically and horizontally. So there is an equally great need here for testing the deposit thoroughly before locating a plant on it.

MARINE CLAYS.

Clayey sediment may be carried by streams into estuaries or to the sea before it settles to the bottom. The latter case especially may yield deposits of wide extent. If these sediments are later covered by a great thickness of additional beds, they become hardened or consolidated to form *shale*. The latter, however, when ground up and mixed with water, may become quite plastic, especially if the individual shale grains cohere by pressure alone.

Shales vary from hard gritty ones like those at Leaksville Junction west of Danville to smooth fine-grained ones like those at Wolftrap.

They may form deposits of considerable thickness, of clean material from top to bottom, or at other times beds of sandstone are interstratified with the shale. As these do not always weather as readily as the shale, their presence even in residual clays derived from shale is at times a source of trouble in excavating.

MINERAL COMPOSITION OF THE PIEDMONT CLAYS.

The mineral composition of the Piedmont clays is shown in tabular form on pages 7 and 8.

The determinative work was done with the petrographic microscope. Samples of each clay were powdered and made into microscopic mounts, the specimens usually being imbedded in Canada balsam. In some cases special determinations had to be made by putting the grains in liquids of higher index of refraction.

The minerals noted were quartz, muscovite, biotite, chlorite, epidote, zoisite, hornblende, feldspar, zircon, tourmaline, rutile, titanite, garnet, magnetite, ilmenite, sericite, hydromica, and kaolinite. The term hydromica^a is used to designate a mineral whose optical characters vary from those of sericite and possibly biotite to kaolinite. There is probably an isomorphous gradation between sericite and kaolinite, at least, with a gradual loss of potash and the addition of water, and in weathering products such as these, hydromica represents a transition stage of weathering toward kaolinite as the final product.

In every clay examined quartz is present, varying in size down to the minimum limit of vision of the microscope. Biotite is nearly as common and usually more or less bleached from loss of iron. Muscovite, strictly speaking, is very rare, the colorless mica of high double refraction generally having that minute scaly character which classes it as sericite. Chlorite is comparatively uncommon, but a few small grains of epidote are to be found in the majority of the clays. Zoisite is present only in the Roseland kaolins and in three of the transported clays, while few are sufficiently fresh to retain the hornblende. Feldspar is commonly seen, although never in large quantity, and the varieties orthoclase, microcline, and plagioclase may be distinguished. Zircon, tourmaline, and rutile are not un-

^a See Galpin, S. L., *Studies of Flint Clays and Their Associates*, Trans. Am. Ceramic Soc., Vol. XIV, pp. 306 and 338, for an excellent discussion of this term.

common, although present in very small amounts, but titanite, garnet, magnetite, and ilmenite are very rare. Sericite has been noted in a few of the clays, but as a rule seems to have gone over into either hydromica or kaolinite. These two latter minerals are never lacking, and although varying in relative abundance, compose most of the finer particles of the clays.

The residual clays are grouped in the table according to the rock formation from which they were derived, with the pegmatitic and similar clays by themselves, and a group at the end to include all the transported clays.

Comparing the different groups, it is noticeable that the transported clays contain a greater variety of minerals than the residual ones. Among the latter the greatest development of kaolinite is found in the kaolins, as might be expected, but in the other clays the mineral composition seems to depend more upon the composition of the original rock and less upon the degree of alteration. The simplicity of the Cambrian residuals and the abundance of quartz and biotite in those derived from the pre-Cambrian granite-gneiss reflect the compositions of their parent rocks.

The symbols A, C, and S are used to denote the relative quantities of the minerals. A indicates that the mineral is relatively abundant, C that it is common, and S, scarce.

A more detailed petrographic discussion of these and other clays tested, together with the practical bearing of the investigations, will be taken up in the final report.

TABLE SHOWING MINERAL COMPOSITION OF PIEDMONT CLAYS.*

(Symbols A, C, and S denote relative quantities of minerals. A, mineral is relatively abundant; C, mineral is common; S, mineral is scarce. For symbol in third column under "Formation" see geological map, Plate I.)

Number	LOCATION	Formation	Quartz	Muscovite	Biotite	Chlorite	Epidote	Zoisite	Hornblende	Feldspar	Zircon	Tourmaline	Rutile	Titanite	Garnet	Magnetite	Ilmenite	Sericite	Hydromica	Kaolinite
2001.	Orange	Tn	A	S															A	C
2002.	"	"	A	S															A	C
2003.	Montpeller	"	A	S															A	C
2008.	Elkwood	"	A	S															A	C
2009.	Brandy	"	A	S															A	C
2013.	Between Culpeper and Elkwood	"	A	S							S		S						A	C
2018.	Culpeper	"	A	S															A	C
2020.	Calverton	"	A	S															A	C
2021.	"	"	A	S															A	C
2037.	Wolftrap	"	A	S															A	C
2039.	Farmville	"	A	S							S								A	C
2073.	"	"	A	S															A	C
2211.	Moseleys Junction	"	A	S							S								A	C
2103.	Arvonla (3 mi. S. S. E.)	Ore	C	C		S						S							A	C
2104.	"	"	C	C		S						S							A	C
2105.	(Ferneliff)	"	C	C		S													A	C
2106.	"	"	C	C		S													A	C
2107.	(Le Sueur)	"	S	A	A	S						S				S			C	S
2108.	"	"	S	A	A	S													C	S
(+2109)	Between New Canton and Arvonla	"	C	A	C							C							C	C
2004.	Orange	Ca	S	A		S													A	S
2005.	Between Orange and Madison Run	"	S	A		S													A	S
2016.	Culpeper	"	S	A		S													A	S
2017.	"	"	A	A															A	S
2026.	City Farm Station	"	C	S							S								C	O
2027.	"	"	C	S															C	O
2056.	Altavista	"	C	S								S							S	S
2075.	Near City Farm	"	S	S								S							A	A
2080.	Gordonsville	"	S	S															A	A
2084.	"	"	C	S															A	A
2085.	"	"	C	S															A	A
2086.	Keswick	"	S	S															A	A
2086.	Charlottesville	"	S	S															A	A
2215.	"	"	C	A									S						A	O
2015.	Culpeper	Ae	A	A		S					S								C	C
2019.	Warrenton (2 mi. N. E.)	"	A	C															A	C
2025.	(S.)	"	C	A															A	C
2035.	Gordonsville	"	S	S															A	C
2048.	Virso (¼ mi. W.)	PCq	C			O													A	S
2066.	Virgilina	PCv	S	A						S									S	S
2092.	Simpleity	"	O	A		S					S								A	C
2011.	Blackstone	PCgr	A	A		S													S	O
2206.	"	"	A	A		S													A	C
2010.	Kenbridge	"	A	A															A	C
2028.	Alberta	"	A	A							S								O	S
2032.	Fredricksburg (S.)	"	A	A					A	S									O	S
2033.	"	"	A	A															S	S
2041.	Virso	"	C	A		S													S	C
2046.	"	"	A	A															A	C
2042.	Meherrin	"	A	A							S		S						A	C
2049.	"	"	C	A															A	C
2049.	Burkeville	"	A	A		S				S	S								A	C
2207.	"	"	A	A		S				O	S								A	C
2051.	Cumberland	"	C	A															S	S
2044.	"	"	A	A						S	S								A	C
2055.	Crozet	"	A	S															A	C
2076.	"	"	S	S							S								A	C
2078.	"	"	C	S															A	C
2057.	Amherst	"	C	S						S				S					A	C
2074.	"	"	S	S															A	C
2083.	"	"	A	S						S									A	C

*These determinations were made by R. E. Somers.

TABLE SHOWING MINERAL COMPOSITION OF PIEDMONT CLAYS.

(Symbols A, C, and S denote relative quantities of minerals. A, mineral is relatively abundant; C, mineral is common; S, mineral is scarce. For symbol in third column under "Formation" see geological map, Plate I.)

Number	LOCATION	Formation	Quartz	Muscovite	Biotite	Chlorite	Epidote	Zoisite	Hornblende	Feldspar	Zircon	Tourmaline	Rutile	Titanite	Garnet	Magnetite	Ilmenite	Sericite	Hydromica	Kaolinite	
2060	Lawrenceville	"	S	A	A							S							O	O	
2061	Dinwiddie	"	A	A	O					S									O	O	
2031	Clarksville	"	A	A	O						S								O	O	
2065	"	"	A	A	O		O			S									A	S	
2066	"	"	A	A	O		O			S									A	S	
2071	"	"	A	A	O	S?	S			O									O	S	
2070	Lacrosse	"	C	O	O														O	S	
2082	Louisa	"	C	O	O		S			S									A	S	
2088	Boynton	"	A	A	S														A	S	
2004	Bedford City	"	A	A	A						S								A	S	
2098	"	"	S	A	A		S												O	S	
2096	"	"	A	A	A														O	S	
2099	Lynchburg	"	O	A	A														A?	A?	
2140	Michaux	"	A	A	A		S				S							S	O	O	
2270	"	"	A	A	A		S												O	O	
2204	Nottoway	"	C	O	A		S												O	O	
2209	Ballsville	"	C	O	A		S			S									O	O	
2210	Powhatan	"	C	O	A		S												O	O	
2212	Moseleys Junction (¼ mi. E.)	"	C	A	C		S												A	O	
2214	Claysville	"	A		C		S			S	S					S			A	S	
2022	Cabin Branch	PCc	A			A	A											O	S	S	
2029	Danville	"	O		O														A	A	
2063	Danville W.	"	A		S		O												A	S	
2072	Chatham	"	O		A		S			S	S								A	S	
2079	Appomattox	"	C	O	O		S												A	O	
2064	Between Appomattox and Pamplin	"	A		O		S					S							O	O	
2086	Pamplin	"	S		O		S												O	O	
2087	Louisa	"	S		A		S			S	S								O	O	
2081	Mineral	"	S		A		S			S	S								O	O	
2100	"	"	A		S		S												A	O	
2198	Motley	"	C		A		S			S		S							S	S	
2030	Pamplin	Pegmatite	O				S												?	A	C
2186	Motley	"	C	C	S					S									O	A	C
2169	Roseland	Crude kaolin	C					O		S									O	A	A
2168	"	Kaolin	O		S			O		S									C	A	A
2167	"	Washed kaolin	S					S		S									C	A	A
2166	"	Tailings	A		S				A	A									O	S	A
2171	Near American Rutile Co.'s Mill	Residual	A		A			A											O	S	A
2006	Culpeper	Flood plain	A		S	S	S	S			S				S				A	S	A
2007	"	"	A		S	C	S			S									O	A	C
2014	"	Transp.	O	S	S		S				S								A	C	O
2023	Stevensburg	"	O			S	S												A	C	O
2043	Reusens	Col.?	A		C		O		A		S		S						A	C	A
2047	"	"	A		S				C										A	A	A
2052	Meherrin	Flood plain	C		C	S	C	S			S		S						A	C	A
2067	Chatham	Col.	A		O		S				S		S						A	A	A
2068	Lawrenceville	Flood plain	C				S				S								A	A?	A
2206	"	"	A				S			S									A	O	C
2009	Brodnax	"	S		S		S				S								A	O	C
2139	Michaux	Transp. Strained from No. 2139	O		S		S				S	S							A	O	C
2077	"	"	S		S						S		S						A	C	A
2040	Danville	Flood plain	A		C		S			S	S	S							C	S	A
2091	"	"	C		C		O	O	S	S									A	S	A
2101	Arvonla	Col.	C		C						S	S							A	S	A
2170	Colleen (1,000 yds. S.)	Wash	A		O		S			O	S		S			S?			S	A	A



(A) Bank of transported clay, Ward Bros.' yard, Galax.



(B) Pit in flood plain clay, Culpeper.

DETAILED DESCRIPTIONS AND TESTS OF THE PIEDMONT CLAYS.**FLOOD PLAIN CLAYS.**

Most of the larger streams in the Piedmont belt, and even many of the smaller ones, are bordered, sometimes for long stretches, by flood-plain terraces. These terraces are of varying width, and may be almost at the stream level or 15 to 20 feet above it.

The surface soil of the terrace is often sandy, while underlying it may be clay or sand, the pockets, lenses, or layers of the two often irregularly distributed. The flood-plain clays are often more plastic and denser-burning than many of the residual clays, and where obtainable seem to be preferred by the brick manufacturer.

Good examples of this type of deposit are worked at Drakes Branch, Danville, Deacon near Lynchburg, and Culpeper.

CULPEPER COUNTY.

Culpeper.—Stream or flood-plain clays are worked at Clarke's brickyard on the northeastern edge of town. The plant is not a very large one, and hence the quantity of clay required is comparatively small. It is supplied from what is probably a flood-plain deposit bordering Mountain Run, but only that portion lying on the south side of the creek is worked. This shows the variable nature so characteristic of many flood-plain deposits. Thus nearest to the works the surface is underlain by a tough blue clay (Lab. No. 2007), about 5 feet thick, while on the farther side of the pit, towards the highway, there is a yellow, less sticky clay (Lab. No. 2006), and again, next to the run the clay becomes very sandy.

The blue clay has too much shrinkage and is too tough to work alone, consequently it is mixed with the yellow, which is of lower shrinkage. The difference in the physical character of the two clays is well shown by the following few tests that were made on them.

Lab. No. 2007, blue clay.—Although this clay is gritty, it is also very plastic. It worked up with 34 per cent water to a mass whose air shrinkage was 8.4 per cent. The bricklets were hard with a good ring even at Cone 010. At Cone 010 the fire shrinkage and absorption were 2 and 13 per cent, respectively, while at Cone 05 they were 4.6 and 12 per cent.

Lab. No. 2006, yellow clay.—This clay, although gritty, has good plasticity. With 24 per cent water it gives a workable paste that shows

5.9 per cent air shrinkage on drying. The clay burns red, and gives a hard body at Cone 05, although at Cone 010 the product is fair. In firing the bricklets, those heated to Cone 010 had a fire shrinkage of 0 per cent, and an absorption of 19.3 per cent, while those fired at Cone 05 showed 1 per cent fire shrinkage, and 15 per cent absorption.

It is seen then that by mixing the two together we overcome the higher shrinkage of the one, and the more porous-burning character of the other.

The output of the yard consists at present of common brick. The clay is prepared by passing through rolls, from which it goes to an end-cut, stiff-mud machine. The bricks are dried under sheds, and burned in scove kilns with permanent side-walls. The product has a good ring.

CAMPBELL COUNTY.

Deacon.—The flood plain bordering James River is underlain by a typical river deposit that varies from sand to plastic sandy clay, there being at times enough of the latter to warrant working it for the manufacture of brick. Such a deposit has been opened up at Deacon, on the Chesapeake and Ohio Railroad, about 6 miles east of Lynchburg, and is utilized by the firm of Adams Bros.-Paynes Co., for making common building brick.

The clay underlying the flood-plain surface averages about 10 feet in depth, but at times is as much as 14 feet. It is excavated by means of a steam shovel, prepared with rolls and pugmill, and molded in a soft-mud machine. Tunnel dryers and permanent side-wall, updraft kilns complete the outfit. The product supplies much of the Lynchburg market.

AMHERST COUNTY.

Reusens.—On the north side of James River, about 500 yards east of the blast furnace of the Oriskany Ore and Iron Corporation, and on the property of T. L. Wills, there is a curious deposit of clay about 50 feet above the river level. It lies higher than the surface of the flood-plain terrace, and is not a recent river deposit; at the same time the presence of a number of rounded pebbles and cobbles in the clay indicate that it is probably some type of transported material, and not a purely residual deposit.

The upper five feet of the deposit is a ferruginous sandy clay (Lab. No. 2047), with scattered, rounded pebbles. Under this is a gray, gritty clay, 4 to 6 feet in thickness (Lab. No. 2043), containing pebbles and cobbles of quartz, coarse feldspar, and biotite schist. The material is interesting, because it serves well for use as a fire-mortar clay and for tamping at the blast furnace.



(A) Brick works at Brodnax.



(B) Clay pit at Brodnax.

There is not much difference between the two clays as the following few tests indicate.

Lab. No. 2047.—A brown, sandy, plastic clay of red-burning character, with 5.8 per cent air shrinkage and low fire shrinkage. It has about 15 per cent absorption at cones 010 and 05.

Lab. No. 2043.—This has 6.1 per cent air shrinkage, very low fire shrinkage, and 13 per cent absorption.

LUNENBURG COUNTY.

Meherrin.—Stream clay is known to occur about 1 mile southwest of Meherrin, on the Richmond and Danville division of the Southern Railway. It is referred to as white, but is of a light gray color, and this fact has led some to think it a fire clay. Indeed it was this rumor which attracted our attention to it. The material (Lab. No. 2052) is a smooth, plastic clay, which shows 5.6 per cent air shrinkage, after being mixed up with 25 per cent water. The clay burns red, and has an excellent ring at Cone 010. At Cone 010 the fire shrinkage and absorption were 1 and 14.2 per cent, respectively. At Cone 05 these two values were 1.4 per cent and 13.1 per cent.

From these few trial tests, the material gives promise of being adapted to the manufacture of a good red brick, but it is not a fire clay.

Virso.—More stream clay occurs at this point about $1\frac{3}{4}$ miles southwest of Meherrin. The material is of light gray color and undoubtedly very similar to the preceding.

BRUNSWICK COUNTY.

Brodnax.—One mile northwest of Brodnax, and about 100 yards south of the Lacrosse-Brodnax road, is an old clay pit of the Chase Brick and Tile Corporation. The deposit lies in a bottom and is a transported clay. It is gray in color, with numerous iron stains, and fairly plastic in its nature.

The clay was hauled to the works with an engine, fed into a screw mixer, then into a pugmill, and end-cut machine. It was dried in steam-heated tunnels, and burned in permanent side-wall, updraft kilns. The yard is not in operation, but the bricks at the plant lacked ring and seemed to be badly laminated.

A sample of the material (Lab. No. 2069) collected by us, worked up with 34 per cent water, had an air shrinkage of 7.2 per cent. The bricklets

burned red with a good ring at Cone 010. At this Cone the fire shrinkage was 1.3 per cent, and absorption 23.2 per cent, while at Cone 05 the fire shrinkage and absorption were 4 and 20.2 per cent, respectively.

This clay makes a good common brick material, although it does not show as low absorption as some of the stream clays of the Piedmont area. It would seem from these tests that the bricks at the yard were not burned hard enough, and that the laminations were due to the machine not being suited to this particular clay.

Lawrenceville.—Transported clays are available at several points around Lawrenceville. Thus, near Great Creek about one-half mile west of town, and just south of the Southern Railway tracks, is a yard owned by W. A. Crinkley, which utilizes a flood-plain clay. The clay is light gray and very plastic, with streaks of limonite. It closely resembles the Brodnax material described above. At the yard the clay is put through rolls, pugmill, and end-cut, stiff-mud machine, dried on pallets, and burned in updraft kilns.

A small sample (Lab. No. 2206) was tested in the laboratory, with the result that it gave with 22 per cent of water a workable mass whose air shrinkage was 4.7 per cent. The material burns red, to a bricklet of moderate absorption, having a good ring at Cone 010, and being nearly steel hard. At Cone 010 the fire shrinkage was zero, and absorption 15.5 per cent. At Cone 05 the fire shrinkage was 1 per cent, and absorption 15.2 per cent. This clay should make a good common brick.

Another flood-plain deposit, located in the flood plain of Rose Creek, is worked northeast of town by the students of St. Paul's College (colored).

The clay is treated with rolls, pugmill, stiff-mud machine, and burned in updraft kilns. The brick are fair, and should be burned harder, for the following tests on a sample from here (Lab. No. 2068) show that the clay burns to a good body at a low heat. It gave with 21 per cent water a workable body of fair plasticity, having 6.3 per cent air shrinkage. The bricklets molded from this burned to a red product, having an excellent ring at Cone 010. The fire shrinkage and absorption at Cone 010 were 1 per cent and 16.8 per cent, respectively, while at Cone 05 the corresponding values were 2.6 per cent and 13.4 per cent.

These preliminary tests point to a good brick clay.

CHARLOTTE COUNTY.

Drakes Branch.—The only clay worked at Drakes Branch, a station on the Richmond and Danville division of the Southern Railway, is a stream



(A) Brickyard of St. Paul's school, Lawrenceville.



(B) Brickyard, Lawrenceville.

deposit which is utilized at Payne and Spindler's yard for making common brick. The yard is located on the southeast side of the railroad, and is equipped with a pugmill, stiff-mud, end-cut brick machine, dryer sheds, and scove kilns. The clay deposit is from 4 to 5 feet in depth, and underlain by sand.

Laboratory tests on this material (Lab. No. 2038) gave the following results: A brown clay of high plasticity, but working up with 23 per cent of water to an easily moldable mass. The air shrinkage was 6.1 per cent, and the average tensile strength 245 pounds per square inch. The clay burns red, with a good color up to Cone 05, but darkens at Cone 03. The bricklets had a good ring even at 010, and burned steel hard at this Cone.

Additional tests are tabulated below:

Cone	Fire shrinkage Per cent	Absorption Per cent
010	.0	15.3
05	.6	14.7
03	2.0	10.3
1	2.0	10.1

This material is a good common-brick clay, which can be worked in a stiff-mud machine. It needs thorough tempering.

PITTSYLVANIA COUNTY.

Danville.—Both residual and stream clays occur in the vicinity of Danville. The latter are found bordering Dan River, and there is a possibility of finding them at a number of points. They are worked, however, only at one point, 2 miles east of Danville, along the Richmond and Danville division of the Southern Railway.

At this point Dothard and Riddle are using a flood-plain clay, running about 8 feet deep, for making common brick. The clay, which is underlain by sand, varies in its nature, there being exposed in the pit two distinct types. One of these is a loamy yellow clay (Lab. No. 2040), which is said to tear if worked alone in the stiff-mud machine. The other is a tough blue clay (Lab. No. 2091), which is said to be too plastic to work alone. The plant is equipped with a pugmill, rolls, end-cut, stiff-mud machine, Steele dryer, and updraft, side-wall kilns.

The following tests were made on three samples, representing the yellow sandy clay (2040), the blue clay (2091), and a mixture of 50 per cent of

each (2216). For purposes of comparison the tests are given in parallel columns.

	2040	2091	2216
Texture	Sandy	Fine	....
Plasticity	Fair	High	Good
Water required	27.4%	27.3%	28%
Air shrinkage	5.8%	6.0%	7.2%
Tensile strength, lbs. per sq. in....	60.0	159.0	102.0
Color burned	Red	Red	Red
<i>Cone 010</i>			
Fire shrinkage	0.0	.6	1.0
Absorption	20.6	19.1	19.8
<i>Cone 05</i>			
Fire shrinkage	0.0	2.0	1.0
Absorption	18.9	16.0	17.8
<i>Cone 03</i>			
Fire shrinkage	1.4	3.0	3.6
Absorption	15.9	11.8	15.7
<i>Cone 1</i>			
Fire shrinkage	2.6	3.0	3.7
Absorption	15.4	12.8	13.9

No. 2040 develops only fair ring at Cone 010, but is steel hard at 03.

No. 2091 gives better body at 010 than No. 2040.

No. 2216 develops good ring at 010.

No. 2091 was run through the die of the stiff-mud machine without difficulty, but it is a tough clay, requiring considerable grinding to break up the lumps. If these are not disintegrated thoroughly the bricks show a tendency to crack. In using a mixture, thorough pugging of the clay is also necessary in order to prevent cracking.

While the clay is used for common brick, it is probable that it could also be used for making drain tile and hollow blocks.

GRAYSON COUNTY.

Galax.—About half a mile southeast of Galax stream clays are being used at Ward Brothers' yard for making common brick. The deposit appears to be a delta, and the cut which has been made for digging the clay is above the level of the flood plain of the near-by stream. In this pit the clay is stratified and the upper 10 feet of the 12-foot face is a brown, smooth, plastic, micaceous clay (Lab. No. 2122).



(A) Flood plain clay, Douthat and Riddle yard, two miles east of Danville.



(B) Clay pit in flood plain deposit, Deacon, east of Lynchburg.

This clay when worked up had 7 per cent air shrinkage. It burned to a red color, and at Cone 010 had a fairly good body. The fire shrinkage and absorption are low. They are:

Cone 010: 1.3 per cent fire shrinkage, 19.9 per cent absorption.

Cone 05: 1.3 per cent fire shrinkage, 18.9 per cent absorption.

This clay should yield a good brick.

Underlying the upper clay, and sharply separated from it, is a bluish-gray clay (Lab. No. 2114) of very plastic character, quite micaceous, and having a somewhat different fire shrinkage, as the tests below show. This, a smooth, plastic material, had 7.1 per cent air shrinkage. It burns to a red color, and forms a body with an excellent ring at Cone 010. At Cone 010 there was .7 per cent fire shrinkage, and 20.8 per cent absorption. At Cone 05, 3 per cent fire shrinkage, and 16.2 per cent absorption.

The two clays are mixed in about equal parts, and the bottom clay improves the quality of the brick; but, if it is not thoroughly pugged, the product shows a tendency to crack.

The bricks are molded in a stiff-mud machine, air dried, and burned in scove kilns. There is a possibility also of making drain tile from these clays.

Two miles east of Galax is W. C. Cole's yard. The clay which lies in a hollow also appears to be of transported character. It is plastic and micaceous (Lab. No. 2117). The pit, which is not over 5 feet deep, shows clays of brown, blue, and light-gray color, but the highly micaceous character, as shown by the following tests, seems to interfere with its making a good hard brick at the temperature of the ordinary scove kiln.

These tests show it to be of low plasticity, and 5 per cent air shrinkage. It burns to a light-red color, and does not give a very hard product. The fire shrinkage up to Cone 05 was 0 per cent, and the absorption 25 per cent.

SUMMARY OF TESTS OF TRANSPORTED CLAYS.

Laboratory No.	LOCALITY	Water required for mixing	Plasticity	Air shrinkage	Tensile strength, lbs. per sq. in.	Cone 010		Cone 05		Cone 03		Cone 1	
						Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption
		Per Cent		Per Cent		Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
2007	Culpeper	34.0	Good	8.4	.....	2.0	13.0	4.6	12.0	.....	.....	.....	.....
2006	Culpeper	24.0	Good	5.9	.....	0.0	19.3	1.0	15.0	.....	.....	.....	.....
2047	Reusens	21.0	Good	5.8	.....	0.0	15.4	0.0	14.7	.....	.....	.....	.....
2043	Reusens	30.0	Good	6.1	.....	0.0	13.0	1.7	13.6	.....	.....	.....	.....
2052	Meherrin	25.0	Good	5.6	.....	1.0	14.2	1.4	13.1	.....	.....	.....	.....
2069	Brodnax	34.0	Fair	7.2	.....	1.3	23.2	4.0	20.2	.....	.....	.....	.....
2206	Lawrenceville	22.0	High	4.7	.....	0.0	15.5	1.0	15.2	.....	.....	.....	.....
2068	Lawrenceville	21.0	Fair	6.3	.....	1.0	16.8	2.6	13.4	.....	.....	.....	.....
2038	Drakes Branch	23.0	High	6.1	245	0.0	15.3	.6	14.7	2.0	10.3	2.0	10.1
2040	Danville, brown	27.0	Fair	5.8	60	0.0	20.6	0.0	18.9	1.4	15.9	2.6	15.4
2091	Danville, blue	27.0	High	6.0	159	.6	19.1	2.0	16.0	3.0	11.8	3.0	12.8
2216	Danville, mixture	28.0	Good	7.2	102	1.0	19.8	1.0	17.8	3.6	15.7	3.7	13.9
2122	Galax	30.0	Good	7.0	.....	1.3	19.9	1.3	18.9	.....	.....	.....	.....
2114	Galax	40.0	Good	7.1	.....	.7	20.8	3.0	16.2	.....	.....	.....	.....
2117	Galax	33.0	Low	5.0	.....	0.0	26.6	0.0	25.2	.....	.....	.....	.....

COMMENTS ON THE TABLE.

The foregoing tests indicate that most of the transported clays examined did not require an excessive amount of water for mixing, but were of good plasticity. The air shrinkage was usually moderate. The tensile strength is variable. Fire shrinkage is high above Cone 010, but most of them show only a moderate absorption. They are therefore good brick clays, and some are adapted to tile making. Those best adapted to tile or even to hollow brick manufacture are the ones tested from Danville, Drakes Branch, and Meherrin.

TRIASSIC CLAYS.

The Triassic formations occupy a number of disconnected areas within the Piedmont province of Virginia.

The first and largest enters the State as a belt about 20 miles wide, with Leesburg, Loudoun County, near its western border, and Manassas, Prince William County, a little farther south, near its eastern margin. This belt, forming the Virginia portion of the New York-Virginia Triassic belt, and comprising parts of Loudoun, Fauquier, Prince William, Culpeper, and Orange counties, narrows rapidly southward, and extends, with the exception of one break north of Orange, as far as Gordonsville. The clays are all residual, red burning, and derived chiefly from shales and shaly sandstones, but in some localities, as south of Culpeper, they are derived from conglomerates. The tests show that this area contains clays of economic value.

A second area, and one containing coal, lies west of Richmond, but few shales of any value have been found in it. The Richmond area includes parts of Amelia, Chesterfield, Henrico, Powhatan, and Goochland counties.

A third one of small size, known as the Scottsville area, lies west of Warren, and comprises parts of Albemarle, Buckingham, and Nelson counties.

A fourth and long belt, known as the Dan River belt, extends north-eastward from the State line through Pittsylvania County into Campbell and Appomattox counties. Most of this area lies remote from the railroad. It is, however, accessible near Chatham and west of Danville, and is crossed by the main line of the Southern Railway between these two points, and again by the Danville and Western Railroad between Danville and Martinsville. West of Danville the shale is too gritty.

There are finally some small areas located, respectively, near Wolftrap, Halifax County, and between Farmville and Cumberland, which contain some good clays.

FAUQUIER COUNTY.

Calverton.—Although the region around Calverton is underlain by a broad area of Triassic rocks, which have weathered to residual clay, there are, owing to the topography, few good exposures of the material. The bedrock seems to be mostly a red, shaly sandstone. Some search was made around this locality for natural exposures of clay, but few good ones were found, and the area should be tested out by boring.

The two following samples may serve to convey some idea of the Triassic residual clay occurring in this region, although it should be remembered that the material may vary from point to point, a fact emphasized by the samples collected between Culpeper and Elkwood to the southwest.

One sample (Lab. No. 2020) collected from a pasture near Calverton was light brown, smooth, and quite sticky, requiring 30 per cent of water for tempering, and having 8 per cent air shrinkage. The air-dried sample showed a few fine cracks. The bricklets burned at Cone 010 had a good ring and good red color, with a fire shrinkage of .3 per cent, and absorption of 17.3 per cent. At Cone 05 the bricklets were steel hard, with a fire shrinkage of 4.3 per cent, and absorption of 10.3 per cent. The material can be classed as a common brick clay, and at Cone 010 should make a salable product.

A second sample (Lab. No. 2021) was taken from the railroad cut on the branch line to Warrenton. The same material shows in the neighboring wagon-road cuts, but here the bedrock does not appear to lie very deep. This is also a good brick clay, and better than the preceding. Its plasticity is fair, and there is little grit. It required 20 per cent of water for working, and the mixture had an air shrinkage of 4.9 per cent, which is not high. At Cone 010 the bricklets had a good ring and red color with a fire shrinkage of 1 per cent, and absorption of 18.9 per cent. At Cone 05 they were steel hard with a fire shrinkage of 6.3 per cent, and absorption of 8.4 per cent.

CULPEPER COUNTY.

Culpeper-Elkwood.—The wagon road from Culpeper to Elkwood traverses the Triassic formation, but there are few heavy cuts either along the railroad or the wagon road. A short distance northeast of where the main highway crosses the railroad, the residual clay from the shale is well exposed in a long, shallow cut. The location here is a good one for working as it is close to the railroad. Above the clay is 1 to 2 feet of sandy loam, which could be mixed in with the clay (Lab. No. 2013). Owing to the favorable location of the deposit a large sample was tested.

This clay worked up with 25 per cent of water to a mass of good plasticity, and 8.3 per cent air shrinkage. The average tensile strength was 95.1 pounds per square inch.

The fire tests of the soft-mud bricklets were as follows:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	0.0	18.9
05	1.7	15.1
03	2.4	14.2
1	2.4	13.92

The clay burned red, and the bricklets had a good ring even at Cone 010, but an excellent one at Cone 05. They were nearly steel hard at Cone 010, and completely so at Cone 03. Dry pressing was also tried, but on account of the fine silty character of the material it did not work very well.

A large sample was put through the stiff-mud machine, but difficulty was encountered in getting it to flow through the die without cracking, and it worked best when treated with the minimum quantity of water. There seems no doubt that it could be made into a good common brick by the soft-mud process, but there is some question as to whether it could be molded stiff mud.

About one-half mile further to the northeast is another exposure of residual clay (Lab. No. 2008), but the weathering here does not appear to be so deep as at the preceding locality. The clay from this locality is very gritty, but fairly plastic. On account of its grittiness it has a low air shrinkage of 4.4 per cent. It burns to an excellent brick with a good ring even at Cone 010, and is nearly steel hard also at this temperature. The fire shrinkage at Cone 010 is low, namely, .7 per cent, and the absorption is moderate, 15.8 per cent. At Cone 05 the fire shrinkage is 7 per cent, and the absorption 4.7 per cent. The material gives promise of making a good brick for general use.

Brandy.—Additional exposures of Triassic clay are to be found around Brandy, but one of the best is at the summit of a hill on the road, 1.5 miles northeast of town, and not more than half a mile in a direct line from the railroad.

The clay (Lab. No. 2009) is well located for working, and the tests given below indicate the possibility of using it. It gives a mass of good plasticity, but high air shrinkage, namely, 11.4 per cent. The clay burns to a good red color, and has a good ring even at Cone 010, becoming steel

hard at this cone. The fire shrinkage and absorption at Cone 010 were, respectively, 3.3 per cent and 22.4 per cent, while at Cone 05 they were 6.4 per cent and 15.6 per cent. The material could be used in brick manufacture, but it would be desirable to mix it with another clay of lower air shrinkage.

Culpeper.—Southeast of Culpeper on the road to Stevensburg there are a number of good exposures of Triassic clays. The best ones are nearest to Culpeper, and the material appears to be very similar to No. 2013, from the Elkwood-Culpeper road.

Stevensburg.—J. W. Legg has a brick and tile yard at this locality, which is intermittently operated, being idle at the time of our visit. The deposit which adjoins the yard is located on higher ground than the surrounding country, but it is probably derived from the Triassic, although it may have been reworked slightly by washing action.

This material (Lab. No. 2023), though of high plasticity, required only 20 per cent of water for mixing, and had an air shrinkage of 7 per cent. It burns to a bricklet with good ring and red color even at Cone 010. At this cone the fire shrinkage was 1.3 per cent, and absorption 11 per cent, while at Cone 05 the fire shrinkage was the same, and the absorption 9.1 per cent.

The clay can be used for common brick and drain tile, and Mr. Legg's yard is equipped with rolls, auger machine for brick and tile, and one circular, updraft kiln.

ORANGE COUNTY.

Orange.—A large, lens-shaped area of Triassic lies west of Orange, and extends, from a point 2 miles north, southward to Gordonsville. While the depth to bedrock seems to vary, there are evidently a number of points where it is possible to get a sufficiency of clay. The Triassic rocks in this area consist of conglomerate, sandstone, and shale, with some volcanics, and the residual clay derived from these may therefore be expected to vary somewhat.

Thus following the wagon road westward from Orange, and parallel with the railroad, a number of Triassic exposures are to be seen. One of these is about $2\frac{1}{4}$ miles from Orange on the Liberty Mills road, the bank being 12 feet high, and not far from the railroad. The material (Lab. No. 2001) is dark red gritty clay, and not used. It has fair plasticity, required 33 per cent of water for mixing, and has a rather high air shrinkage of 10 per cent. It burns to a fair brick of red-brown color at

Cone 010, with a fire shrinkage of 1 per cent, and an absorption of 21.7 per cent, which is rather high. At Cone 05 the brick is steel hard, with a good ring, 4 per cent fire shrinkage, and 15.3 per cent absorption.

The material could be used for common brick, and could probably be mixed up with less water, so as to reduce the air shrinkage.

About three-fifths of a mile east of Liberty Mills the Triassic still outcrops, but the clay here is more gritty. The interesting feature of this clay (Lab. No. 2002) is that it is residual from conglomerate. While the pebbles are pretty well decomposed, the clay is nevertheless somewhat gritty. The plasticity is fair and the air shrinkage 8.7 per cent. It gave a fair bricklet at Cone 010, of brownish-red color, and, while hard enough for use, the clay did not actually become steel hard until above Cone 05. At Cone 010 the fire shrinkage was 1 per cent, and absorption 18.8 per cent, while at Cone 05 these two values were, respectively, 1.6 per cent and 17.4 per cent. The material should work for common brick.

The decomposed conglomerate is exposed again in a new cut of the Southern Railway southwest of Montpelier. At Montpelier station there is a shallow cut in decayed conglomerate, which is more decomposed than any of the others, and consists of yellowish clay above. A large sample (Lab. No. 2003) was tested from this locality, as the exposure of material was good, and the general character is similar to No. 2002.

The plasticity developed by mixing with 30 per cent of water was fair, the average air shrinkage 7 per cent, and the average tensile strength, when air dried, 69 pounds per square inch. The soft-mud bricklets yielded the following results:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	Too soft for brick	....
05	2.7	16.3
1	3.0	16.8

The clay gives a fair brick at Cone 05, but the color is not a good red. At Cone 1 it is steel hard. A dry-press bricklet was tried, but did not yield a sound enough body.

A sample of the clay was then put through the stiff-mud machine, and flowed through both the brick and hollow-brick dies without any trouble. It would be necessary, however, to put the clay through a rolls before molding in order to crush the pebbles, as these would interfere with the cutting wires. The bricklets made from the stiff-mud mixture were a

little more absorbent at Cone 010, but showed the same absorption at Cone 03 as the soft-mud bricklets at Cone 1.

This clay could be used, we believe, for the manufacture of both common and hollow brick. It does not burn dense enough for drain tile.

PRINCE EDWARD COUNTY

Farmville.—There is evidently considerable Triassic clay in the vicinity of Farmville, and some of it was used a number of years ago for making brick. One of the best exposures is at the end of Ely Street, where an excavation has been made by Thos. A. Bolling for making brick. The clay is red and plastic near the surface, but about 3 feet down shows considerable mica. The material (Lab. No. 2039) is well located for transportation, and hence a large sample was tested.

The clay shows considerable sand and mica, the small scales of the latter being noticeable in the burned brick. With 36 per cent of water the clay worked up to a mass of fair plasticity, whose average air shrinkage was 6 per cent, and average tensile strength 90.4 pounds per square inch.

The fire tests on the soft-mud bricklets resulted as follows:

Cone	Fire shrinkage Per cent	Absorption Per cent
010	1.0	23.1
05	4.0	17.9
03	5.0	15.1

The clay burns to a red color, with a fair ring at Cone 010, and a good ring at Cone 05. It became steel hard at Cone 03. The material can be considered suitable for common brick, although the absorption is a little higher than desirable at Cone 010. Attempts to mold the bricklets dry press did not yield encouraging results.

Bolling's yard was equipped with a soft-mud machine, operated by horse-power. The product, which was burned in scove kilns, was not fired hard enough.

On High Street, 1 mile northwest of town, a blue-gray, very sticky clay is to be found. It is probably residual from shale or shaly sandstone, and there is an exposure of it about 100 feet long and 8 feet high, without any bedrock showing.

As the tests show, it (Lab. No. 2073) is a good brick material, and though from the same formation, it yields results quite unlike those obtained on testing No. 2039, and is of better grade.



(A) Horse-power pug mill, Bolling's yard, Farmville.



(B) Clay bank, Ivey's brickyard, Chatham.

The clay worked up with 24 per cent of water to a mass of good plasticity, whose air shrinkage was 5.1 per cent, and average tensile strength 131.7 pounds per square inch. It was tested both by molding soft mud, and by running it through the stiff-mud machine.

The soft-mud tests were as follows:

Cone	Fire shrinkage Per cent	Absorption Per cent
010	.3	16.4
05	.3	16.2
03	1.3	11.7
1	1.7	11.0

These bricklets show a low fire shrinkage, and moderate absorption. They were steel hard at Cone 03, but had a fair ring even at Cone 010. At this cone the color was light red, but deepened at Cone 05.

A sample was put through the stiff-mud machine, and flowed easily through the brick die without cracking. There are scattered pebbles in the clay, which would have to be eliminated by means of a rolls. The product from this machine gave a fair brick at Cone 010. This clay could be used for common brick, and might even work for hollow brick.

HALIFAX COUNTY.

Wolftrap.—There is a small elliptical area of Triassic, about 8 miles long, lying north and west of the railway in this vicinity, while a second area of about the same size lies 24 miles to the north in Charlotte County.

One mile northeast of Wolftrap station there is an excellent section of the Triassic in the railroad cut. The material exposed is a smooth, brownish-red shale, which grinds up easily, and in its upper part is completely weathered to a plastic clay. This clay underlies the field and slopes to the west of the track, and has there been utilized for making common brick by the Boston Brick Co. They have not employed any of the shale, as the residual clay has thus far been sufficient for their needs.

The product now being made from the clay consists of common brick, the plant being equipped with a disintegrator, rolls, pugmill, end-cut, stiff-mud machine, and dryer.

The shale deposit is the most important material to consider here, for it represents one of the best deposits of plastic materials seen in the Piedmont Plateau region. This is a smooth, brownish-red shale (Lab. No. 2037) that worked up to a mass of excellent plasticity with 35 per cent of water, and 10 per cent air shrinkage, which is too high and would have

to be reduced, probably by adding some of the neighboring sandy residual soil. The average tensile strength was 200 pounds per square inch.

On testing the soft-mud bricklets the following results were obtained:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	2.0	22.4
05	4.0	17.1
03	5.7	8.90
1	6.0	7.00

The clay burns to a red color, has an excellent ring even at Cone 010, and is steel hard at Cone 03. A sample tested in the stiff-mud machine worked well in both the brick and the tile dies, and gave a good hard product.

The shale could probably be used for common brick, hollow brick, and drain tile. It would also work for dry-press brick. Indeed it is one of the best clays tested from the Piedmont region.

PITTSYLVANIA COUNTY.

Leaksville Junction.—The Triassic shale at this locality is quite different from the Wolftrap material, for it is exceedingly gritty, and is interstratified with occasional beds of sandstone, which have to be thrown out in quarrying the shale.

The shale is hard and does not grind readily, moreover it possesses low plasticity, and the fact that it could be worked is due to the loamy overburden being mixed with it. As the cut becomes deeper, there would not be enough of this to mix with the shale. So, on the whole, unless enough clay is available to mix with the shale, it is not to be regarded as a very desirable proposition.



(A) Triassic shale in cut, one mile north of Wolftrap.



(B) Triassic shale at brick works near Leaksville Junction.

SUMMARY OF TESTS OF TRIASSIC CLAYS.

Laboratory No.	LOCALITY	Water required for mixing	Plasticity	Air shrinkage	Tensile strength, lbs. per sq. in.	Cone 010		Cone 05		Cone 03		Cone 1	
						Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption
		Per Cent		Per Cent		Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
2020	Calverton	30.0	Fair	8.0	.....	0.3	17.3	4.3	10.1	.....	.....	.....	.....
2021	Calverton	20.0	Fair	4.9	.....	1.0	18.9	6.3	8.4	.....	.....	.....	.....
2013	Culpeper	25.0	Good	8.35	95.15	0.0	18.9	1.7	15.1	.....	.....	.....	.....
2008	Culpeper	45.0	.....	4.4	.....	0.7	15.8	7.0	4.6	2.4	14.2	2.4	13.92
2009	Brandy	49.0	Good	11.4	.....	3.3	22.4	6.4	15.6	.....	.....	.....	.....
2023	Stevensburg	20.0	High	7.0	.....	1.3	11.0	1.3	9.1	.....	.....	.....	.....
2001	Orange	33.0	Fair	10.0	.....	1.0	21.7	4.0	15.3	.....	.....	.....	.....
2002	Orange	36.0	.....	8.7	.....	1.0	18.8	1.6	17.4	.....	.....	.....	.....
2003	Montpelier	30.0	Fair	7.7	69.01	.....	.....	2.7	16.3	.....	.....	3.0	16.9
2039	Farmville	37.0	Fair	6.0	90.4	1.0	23.1	4.0	17.9	5.0	15.1	.....	.....
2073	Farmville	24.0	Good	5.1	132.0	0.3	16.4	0.3	16.2	1.3	11.7	1.7	11.0
2037	Wolftrap	35.0	Good	11.5	200.0	2.0	22.4	4.0	17.1	.....	.....	6.0	7.0

COMMENTS ON THE TABLE.

The Triassic clays show a variable amount of water required for mixing, but the quantity is not always high. The plasticity is fair to good, and the air shrinkage is variable, but in most cases not too high for use. It is to be especially noticed that not a few of the shales burn to a fairly dense body at Cone 05. While all the clays make common brick, the absorption at Cone 010 is at times rather high. Certain ones like those tested from Farmville, Montpelier, and Wolftrap would do for the manufacture of hollow brick. The Wolftrap material is also suited for the manufacture of drain tile and dry-pressed brick.

ORDOVICIAN CLAYS.

PRINCE WILLIAM COUNTY.

Quantico.—Six miles west of Quantico Station, near Dumfries, is the Cabin Branch pyrite mine. The pyrite body is enclosed between schists, which are weathered on the outcrops. In putting down a new shaft at the mine 18 feet of residual clay were passed through, and then 60 feet of what appeared to be disintegrated biotite schist. The material was fairly solid when thrown on the dump, but crumbled readily to a mass that resembled clayey sand.

As the question was raised whether this material would do for brick manufacture, a large sample (Lab. No. 2022) was put through some physical tests. The material is a dark gray, sandy clay of slight plasticity, and 5 per cent air shrinkage. The average tensile strength was 67 pounds per square inch.

The chief difficulty with the material is its low plasticity in the raw state. But in burning the soft-mud bricklets had a body at Cone 010 that was surprisingly solid and gave a fair ring, although the clay did not actually burn steel hard until Cone 03.

The firing tests gave the results shown below:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	.6	26.3
05	2.0	22.2
03	3.0	8.6
1	4.3	8.4

The clay burns reddish and is steel hard at Cone 03, but has a fair ring at Cone 010; and, while it is by no means an ideal brick material, it could be used if necessary.



(A) Clay overlying slate, north of Arvonnia.



(B) Section showing sharp contact between clay and slate shown in view above.

BUCKINGHAM COUNTY.

Arvon.—The Ordovician slates at this locality have been actively worked for many years for roofing purposes, but as usual the amount of waste is very large, accumulating in dump piles of considerable size, for which there is no use at the present time. The problem that presented itself here, therefore, was to determine whether the slate refuse could be used for common-brick manufacture.

The fresh slate, even if finely ground, has too little plasticity to permit its being molded, so we have the possible alternative of mixing the slate with clay, the latter representing the residual material derived from the weathering of the slate.

An examination of a number of quarries in the district showed that the depth and extent of weathering is exceedingly variable. Thus at the Williams quarry near the station there is very little weathered rock, while at the Pitts and LeSueur quarries the slate though hard is slightly weathered to a depth of 15 to 30 feet, and it is claimed that this material can be used for making dry-pressed brick. On the other hand at the quarry of the Arvon Slate Co., 2 miles south of Arvon, and at Ferncliff, 2 miles north of Arvon, plastic, residual clay overlies the slate.

In order to get some definite information of the possible use of the slate for clay products, several samples were collected and tested.

The first investigated was the slate of Williams quarry, which was mixed with clay from a cut along the railroad about a quarter of a mile north of Arvon. This is a tough, ferruginous clay resting directly on the slate, but sharply separated from it. The clay is usually quite plastic, but in places it is loamy or sandy, and contains rounded quartz pebbles. It is probably a colluvial clay, and the exposure is about 400 feet long and 8 to 10 feet deep.

A mixture (Lab. No. 2101) was made up of 75 per cent slate refuse ground to pass through an $\frac{1}{8}$ -inch crusher opening, and 25 per cent of the clay from one mile north of Arvon. Some of the slate became rather finely crushed in putting it through the crusher. This mixture worked up to a fairly plastic mass with 18 per cent water, whose air shrinkage was 1.7 per cent, and average tensile strength about 25 pounds per square inch.

It was possible to mold it into bricklets without any difficulty, and these became steel hard, deep red in color, and had a good ring if fired to Cone 05.

The other firing tests were:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	0.0	14.3
05	0.0	13.5
1	0.0	10.8

The very low fire shrinkage, due to the gritty character of the slate, is quite noticeable, but the clay which fills in the voids keeps the absorption low. If desired, it would be perfectly possible to use this mixture for brick making, and the rough slate grains scattered through the clay would help to roughen the surface, if the mixture were used for making rough-texture brick.

At the quarry of the Arvon Slate Co., already referred to, the residual clay shows in the quarry above the slate, and also in the slope to the west of the quarry where several prospect trenches have been dug. One of these is 3 feet deep and all clay; the other is 9 feet deep and mostly clay, there being some partly-weathered rock in the bottom.

The residual clay from the 3-foot trench (Lab. No. 2103) is smooth and plastic, and worked up with 35 per cent of water. The air shrinkage was 8 per cent. The clay burns to a good color, but not to a very dense body. Thus at Cone 010 the fire shrinkage and absorption were, respectively, 1 per cent and 27.9 per cent, while at Cone 05 they were 3.4 and 24.8 per cent. So while this particular part of the deposit gives a sound brick, at a low heat, the product is very porous.

Comparing the above with another sample (Lab. No. 2104) from the 9-foot trench on the same property, and including a little partly-weathered slate in the sample, we find some interesting differences. This mixture is smooth and plastic, but required only 30 per cent of water to work it up, and had an average air shrinkage of only 2.4 per cent. The average tensile strength was low, being not over 10 pounds per square inch. The bricklets had a good ring at Cone 05, and an excellent one at Cone 03. They burn to a red color. The other firing tests were as follows:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	Too soft to use	....
05	.7	24.0
03	2.7	17.2
1	4.0	15.8

The clay should be burned to Cone 03 to give a good brick, and if there is a sufficient quantity of the clay it could be employed for this purpose.

The variation in the character of the material could be adjusted by using a mixture from different parts of the deposit.

The slightly weathered slate (Lab. No. 2106) from the LeSueur quarry was also tried out. This when ground up is of too low plasticity to mold. It can be dry pressed, if care is used, but it takes too much care for commercial purposes. The best way to treat this would be to mix it with a little plastic clay.

At Ferncliff, north of Arvonnia, the gullies on the hillside above the quarry indicate rather widespread residual clay, but our actual knowledge of its depth does not exceed 3 feet.

The decayed schists along the main road between Arvonnia and Bremono Bluff do not offer much promise.

SUMMARY OF TESTS OF ORDOVICIAN CLAYS.

Laboratory No.	Locality	Water required for mixing		Plasticity	Air shrinkage		Tensile strength lbs. per sq. in.		Clone 010		Clone 05		Clone 03		Clone 1	
		Per cent			Per cent		Less than		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
							10.0		Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption
2101	Arvonla slate and clay.....	18.0	Fair	.....	1.7	Less than	25.0	.....	0.0	14.8	0.0	18.5	.....	.....	0.0	10.8
2103	Basinual clay, Arvon Slate Co.....	35.0	.....	.....	8.0	Less than	10.0	.....	1.0	27.9	3.4	23.8	.....	.....	.....	.....
2104	Clay and weathered rock, Arvonla...	20.8	Good	.....	2.4	Less than	10.0	.....	.....	.....	0.7	24.0	2.7	17.2	4.0	15.8
2105	LeMueur quarry.....	30.7	Low	.....	0.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2105	Furnell quarry	46.0	Good	.....	10.8	.....	.....	.....	2.7	30.8	5.4	25.2	.....	.....	.....	.....



(A) New cut on Southern Railway near Orange.



(B) Old cut near City Farm station, southeast of Lynchburg. Residual clay from rocks of Cambrian age.

COMMENTS ON THE TABLE.

The residual clays from the slate can be used for making brick. The best results were obtained by using ground slate waste from the quarries and the clay found north of Arvonía, a mixture that should work well for rough-textured brick.

CAMBRIAN CLAYS.

The Cambrian formations occupy rather narrow belts in the western part of the Piedmont region. (See map, Plate I, in pocket.) These belts, which coalesce to form one south of Charlottesville, extend all the way across the State. The rocks from which the residual clays are derived are chiefly schists. The clays are not as important as those from the other formations, partly on account of their location, and partly because they do not always burn to as good a brick as the other clays.

Residual clays derived from the Cambrian rocks were tested at some six different localities discussed below.

ORANGE COUNTY.

Orange.—There is a considerable quantity of residual clay from the Cambrian to be found around Orange, but none of it is being used at the present time. The best exposures are in two large cuts along the new line of the Southern Railway about one mile west of Orange. The second cut shows red and brown residual clay, with a maximum exposed depth of 40 feet. The clay is soft and plastic when wet, but not very sticky, and there are many slicken-sided surfaces coated with limonite. Numerous cross joints, emphasized by streaks and films of limonite, cut through the clay. No solid rock shows in the cut.

The material (Lab. No. 2004) is residual clay derived from gneiss. It has fair plasticity, but takes considerable water to mix, namely, 43 per cent. The air shrinkage is low, 3.3 per cent, and so is the average tensile strength, which does not exceed 10 pounds per square inch.

The soft-mud bricklets burned to a bright red color, and, while they were not hard enough at Cone 010, gave a fair product at Cone 05.

The other firing tests were as below:

Cone	Fire shrinkage Per cent	Absorption Per cent
05	4.6	37.0
03	5.3	37.0
1	5.3	35.6

The main objection to the bricklets is their very high absorption. A large sample tested in the stiff-mud machine worked through the die without any trouble.

While the material could be utilized for the manufacture of common brick to be used in small structures, a denser and harder-burning clay is desirable.

Following across the Cambrian from Orange to Madison Run, there are many outcrops of bedrock, and occasional cuts in residual clay, much of which is similar to that in the large cut previously mentioned.

About three-quarters of a mile northeast of Madison Run, the phyllites are decomposed to a moderately plastic clay (Lab. No. 2005). Other shallow exposures are to be seen northwest of Madison Run station, and not far from the station is an old church built before the war of brick made from the local clay. Most of these are still in good condition.

A few tests made on the clay derived from the phyllite are given below. This clay (Lab. No. 2005), though derived from the same formation but a more schistose rock than No. 2004, is quite contrasted to it so far as tested. Though gritty, it has fair plasticity, and took 38 per cent of water to develop it. The air shrinkage was 8.2 per cent. At Cone 010 the soft-mud bricklets had a fire shrinkage of 2 per cent, and an absorption of 20 per cent, while at Cone 05 these were 6.4 per cent and 12.20 per cent, respectively. The bricklets had a good ring at Cone 05, although the product could be burned at a slightly lower temperature. The color after burning is red.

Judging from these tests, this clay should make a much better brick than the preceding one.

Additional good exposures of Cambrian residual clays are found along the Southern Railway, about half a mile north of Orange. The clay is red on the surface, but yellowish below, and is quite sticky.

A very red sticky clay was formerly worked by Hatcher and Gaither near Orange, but the product, due partly to insufficient burning, was not very hard. No brick have been made since 1912.

Gordonsville.—Cuts in Cambrian residual clays are numerous to the southeast of Gordonsville, but few of them are deep. The material exposed in them, however, exhibits considerable similarity.

The best cut seen is located about $2\frac{1}{4}$ miles southeast of town on the road to Mechanicsville, and shows a section of residual clay about 8 feet

deep derived from schist. The upper part of the section is thoroughly weathered, but the lower third still shows the schistose structure of the parent rock. There are scattered veinlets of quartz, but on the whole the material is sufficiently plastic to mold as shown by the following tests.

The material (Lab. No. 2095) is a smooth red clay, which worked up with 39 per cent of water to a mass of good plasticity, whose air shrinkage was 8.3 per cent, and average tensile strength 65 pounds per square inch. The soft-mud bricklets burned to a good red color, but did not give a good ringing product unless burned to at least Cone 05, and became steel hard at Cone 03. The fire shrinkage is not high, but a desirably low absorption was not obtained unless burned to Cone 1, although that noted at Cone 010 is not higher than that of many of the common brick now made in the Piedmont.

The fire tests made on the soft-mud bricklets are tabulated below:

Cone	Fire shrinkage Per cent	Absorption Per cent
010	0.0	26.7
03	2.7	28.4
1	3.7	18.7

A sample tested in the stiff-mud machine flowed through the brick die without any difficulty. The clay contains some stony lumps, however, which must be broken up before it is put through the machine. This clay is to be classed as a fair common-brick clay.

Other Cambrian clays are found to the northwest of Gordonsville. Thus on the Barbourville road, about a third of a mile northwest of town, there is a section about 200 feet long, with a maximum depth of 10 feet. The clay is at times stony, but the pebbles were broken up in grinding the sample. The latter was taken from the top to the bottom of the cut.

The clay (Lab. No. 2080), although sandy to the feel, and moderately plastic, should be useful for common-brick manufacture. Its air shrinkage after mixing with 35 per cent of water is 7.9 per cent. The bricklets burned to a good red color, and had a good ring even at Cone 010, although the absorption was rather high. The fire shrinkage and absorption at Cone 010 were, respectively, .7 and 26.4 per cent, and at Cone 05, 3, and 19.2 per cent.

A little further west on the same road is another cut, 150 feet long with a maximum depth of 12 feet. Similar clay shows in the hills around this point, and so it was thought desirable to sample it. The tests show it to be a red, smooth clay (Lab. No. 2084) of high plasticity, which when

worked up with 39 per cent of water had an air shrinkage of 8.3 per cent, and a tensile strength of 49 pounds per square inch.

The clay differs somewhat from many of the other samples tested, for while it maintains a good red color up to Cone 03, above that it darkens, shrinks, and cracks so badly as to be worthless. Below the temperature mentioned the color and ring are good, although the bricklets at times cracked a little. It was steel hard at Cone 05.

Other firing tests are as below:

Cone	Fire shrinkage Per cent	Absorption Per cent
010	2.3	22.8
05	4.0	19.4
03	8.3	5.85
1	11.0	5.9

The clay would probably work in a stiff-mud machine. It could be used for brick manufacture. These residual clays from Cambrian show at other points along the road nearly to the base of Southwest Mountain.

ALBEMARLE COUNTY.

Charlottesville.—Residual clays derived from the Cambrian schists and the Catoclin schist (altered basalt) of pre-Cambrian (Algonkian) age occur, but the clays derived from the Cambrian rocks are the only ones that have thus far been utilized in the manufacture of common brick. Of the two brick plants recently operated at Charlottesville, only one is running at present.

Keswick.—The bedrock around Keswick is schistose and slaty, and there are but few exposures of clay within a mile of the town.

One found about a quarter of a mile southwest of Keswick was put through a few tests. The material (Lab. No. 2085) from here is a dark brown, sandy clay, with good plasticity. The addition of 30 per cent of water gave a workable mass whose average air shrinkage was 5.6 per cent, and at Cone 05 it gave a good brick. The fire shrinkage and absorption at Cone 010 were 1.3 and 24.4 per cent, respectively, while at Cone 05 they were 2.3 and 19.7 per cent.

Although the absorption is a little high, there is no objection to employing this material for common-brick manufacture.

CAMPBELL COUNTY.

City Farm Station.—In an abandoned cut of the Southern Railway there is one of the best exposures of residual clay from the Cambrian rocks that we investigated. The section is about 20 feet thick, and the clay appears to be derived from schist, but on account of slide material it was not possible to section the full thickness of the deposit.

Of the two following samples, No. 2026-7 represents the upper 8 feet, and No. 2075 the next lower 4 feet. The clay from the upper part of the cut (Lab. No. 2026-7) is red-brown and fairly plastic. Its air shrinkage was 7 per cent, and average tensile strength not over 15 pounds per square inch. At Cone 010 it was too soft for a good brick, but at Cone 05 while hard enough the absorption was too high, namely, 31.6 per cent. This high porosity was accompanied by an almost negligible fire shrinkage.

The material from lower down in the cut (Lab. No. 2075) was very similar, for while its air shrinkage was a little lower, 5.2 per cent, the absorption at Cone 05 was also high, 30.6 per cent, and the fire shrinkage very low.

These clays could be used for common brick, but materials with lower absorption and denser-burning qualities should be sought.

Lynchburg.—The only locality near Lynchburg, where the Cambrian has been worked, is at the plant of the DeWitt brick works, 2 miles west of Lynchburg, on the Norfolk and Western Railway.

The material (Lab. No. 2099) appears to be residual from a schist, but the deepest lies on a hill slope, and may have been moved somewhat by slide, as well as being reworked a little by water. Scattered through it are schist fragments.

The clay is fairly plastic, and required 38 per cent of water to work it up. The air shrinkage was 8.7 per cent, and the average tensile strength 69 pounds per square inch. The bricklets after burning had a good red color, but did not develop a good ring unless burned to Cone 05. The absorption is moderate above Cone 05.

The fire shrinkage and absorption, at the several cones, were as below:

Cone	Fire shrinkage Per cent	Absorption Per cent
010	.0	26.7
05	.0	25.1
03	2.4	16.4
1	4.4	16.9

A second lot was tested in the stiff-mud machine, but could not be made to flow through the die without tearing badly. The material could be used for common brick, if molded in a soft-mud machine, but it must be well burned to give a marketable product.

Altavista.—No bricks are now made at this locality, but there is an abandoned brickyard on the south side of the Virginian Railroad, about a quarter of a mile northeast of the town. The clay (Lab. No. 2056) is residual from schist, and has been excavated to a depth of 4 to 6 feet, the upper part being quite uniform, but becoming mottled with depth. No bedrock was struck, and we do not know how deep the deposit is.

The clay is of good plasticity, with an air shrinkage of 7.9 per cent. It burns to a red brick, and has a sound ring even at Cone 010.

The fire shrinkage and absorption at different cones are given below :

Cone	Fire shrinkage	Absorption
	<i>Per cent</i>	<i>Per cent</i>
010	.7	25.9
05	1.7	23.4
03	5.0	15.0
1	5.0	15.8

These tests show low fire shrinkage up to Cone 05, with rather strong absorption, but above that a moderate fire shrinkage with only moderate absorption.

The clay should work for a common brick, but the yard ceased operations about two years ago, although the location is an excellent one, and there seems no reason why the clay should not make a salable product if properly handled.

SUMMARY OF TESTS OF CAMBRIAN CLAYS.

Laboratory No.	LOCALITY	Water required for mixing	Plasticity	Air shrinkage	Tensile strength, lbs. per sq. in.	Cone 010		Cone 05		Cone 03		Cone 1	
						Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption
		Per Cent		Per Cent	Less than	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
2004	Orange	43.0	Fair	3.0	10.0	1.0	.....	4.6	37.0	5.3	37.0	5.3	35.6
2005	Madison Run	38.0	Good	8.2	.....	2.0	20.0	6.4	12.2	2.7	28.4	3.7	18.7
2085	Gordonsville	39.0	Good	8.3	65.0	0.0	26.7	.....	.....	.....	.....	.....	.....
2080	Gordonsville	35.0	Fair	7.9	.....	0.7	26.4	3.0	19.2	.....	.....	.....	.....
2084	Gordonsville	39.0	High	8.3	49.0	2.3	22.8	4.0	19.4	8.3	5.8	11.0	5.9
2085	Keswick	30.0	.....	5.6	.....	1.3	24.4	2.3	19.7	.....	.....	.....	.....
2026-7	City Farm Station	45.0	Fair	7.0	Less than	0.0	.....	0.0	31.6	.....	.....	.....	.....
2075	City Farm Station	39.0	Fair	5.2	15.0	0.3	30.6	1.0	30.6	.....	.....	.....	.....
2099	Lynchburg	30.0	Fair	7.9	.....	0.3	27.1	2.0	25.0	.....	.....	.....	.....
2056	Altavista .....	.....	Good	7.9	.....	0.7	25.9	1.7	23.4	5.0	15.0	5.0	15.8

COMMENTS ON THE TABLE.

The residual clays derived from the Cambrian rocks usually required a considerable amount of water for mixing, and had at least fair plasticity. The air shrinkage is variable, and not directly related to the amount of water required. The fire shrinkage was low at Cone 010, but variable at Cone 05. The absorption of all was rather high at Cone 010, but with some it decreased considerably at Cone 05. The Cambrian clays can nearly all be used for the manufacture of common brick, but they are the least desirable of any of the classes of residual clays tested, for the reason that most of them burn to a very porous body. This is due in part at least to their micaceous character.

ALGONKIAN CLAYS.

Reference to the map, Plate I, will show the extension southwestward from Maryland into Virginia of two approximately parallel but irregular narrow belts of dark basic igneous rocks (basalt and diabase) of pre-Cambrian (Algonkian) age, and designated Catoctin schist. The rocks of these two belts have been more or less altered by metamorphism into chlorite and epidote aggregates, and are schistose in character.

The more westerly of the belts is confined to the Blue Ridge Mountains, and extends southwestward from the Potomac almost to the James. The second belt extends from north-central Loudoun County southwestward to a point south of the central portion of Albemarle County. Warrenton and Culpeper are located on this belt, while Orange and Gordonsville are situated only a short distance east of it, and Charlottesville lies on the western margin not far from its southernmost extension.

The Catoctin schist yields normally a highly ferruginous dark red clay which can be used for brick manufacture, but it seems to be inferior to that derived from some of the other formations.

FAUQUIER COUNTY.

Warrenton.—The region around Warrenton is underlain by Catoctin schists, but there are comparatively few exposures of clay, in spite of the hilly character of the region. Such cuts as there are appear chiefly along the high roads.

From these road-cut sections it would appear that the character of the schists is variable, and consequently also the character of the residual clays. Where the bedrock contains more or less biotite and feldspar it seems to

give rise to a tough, often plastic clay, but in other places, as on the north side of Baldwin's Ridge and on the New Baltimore turnpike, the schist contains so much muscovite and quartz as to weather to a light-colored, very sandy clay, known locally as sand, and of no use in brickmaking. All the bricks used in Warrenton come from Alexandria.

One sample was tested from the vicinity of Warrenton. This was collected about 2 miles northeast of town, on the road from Auburn to the New Baltimore turnpike; and, while the location is not favorable for a brick plant, the material represents the better type of clay to be found in this vicinity.

The clay (Lab. No. 2019) which is residual from diabase is of moderate plasticity, and, when mixed up with 36.6 per cent water, had an air shrinkage of 6.4 per cent, and an average tensile strength of 71 pounds per square inch. It burned to a good red color, and was steel hard with a good ring at Cone 03, although even at Cone 05 it would probably be hard enough for common brick. The absorption below Cone 03 is a little higher than is desired, but at the last-named cone is not excessive.

The other fire tests on the soft-mud brick follow:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	2.3	27.0
05	3.0	23.5
03	4.4	18.11
1	6.0	17.70

A sample tried in the stiff-mud machine ran through the brick die fairly well, although at times it showed a tendency to crack, but this may have been due to the fact that the die was not thoroughly adapted to this type of clay. The material did not dry-press successfully. It is to be classed as a red-burning brick clay.

Another sample (Lab. No. 2025) taken from a small cut south of Warrenton was fairly plastic, had 5.6 per cent air shrinkage, and, while the bricklet at Cone 010 was fair, the absorption was very high, namely, 30 per cent.

CULPEPER COUNTY.

Culpeper.—The residual clays from the Catoctin schist are found in limited amounts west of Culpeper, especially to the southwest on the road towards Fordville. But while clays are not scarce, there are few large outcrops. The best was seen about a mile southwest of Culpeper, where a bank about 75 feet long can be examined. There is not enough material

here to warrant starting a yard, and a small sample (Lab. No. 2015) was put through a few tests, to compare with the other Catoctin clays. The results of these tests follow:

This material (Lab. No. 2015) was a yellowish-brown, gritty clay, which with 22 per cent of water gave a mass having 4.5 per cent air shrinkage. The few tests made on this sample indicate that it burns to a better body than most of the Catoctin clays tested, giving a fair bricklet at Cone 010, and a good one at Cone 05. The fire shrinkage at both cones mentioned is zero, and the absorption at Cone 010 is 18.5 per cent, and at Cone 05, 15.3 per cent. Material of this character should make a good brick.

A second sample was taken from a pit, where Mr. Clarke of the brick works is said to have obtained a trial load of clay. This deposit is near the creek, about a half to three-quarters of a mile west of town, and the material is probably of colluvial nature. It is a light brown, gritty clay (Lab. No. 2014), which worked up with 38 per cent of water, and had 11.3 per cent air shrinkage. One sample burned at Cone 010 showed zero fire shrinkage, and 27.8 per cent absorption. It is not to be recommended as a good brick clay. About 50 yards from this pit is another one of undoubted residual character.

About half a mile west of south from Culpeper is a residual clay, which seems to result from the weathering of a conglomerate made up largely of material derived from the Catoctin. There is an outcrop about 200 feet long and 6 feet high. The material is a red, slightly gritty clay (Lab. No. 2016), which took up 34 per cent water in mixing, and had an air shrinkage of 7.5 per cent. It burns red, but does not give a very hard product, the absorption even at Cone 05 being rather high.

Two miles southwest of Culpeper, the residual clay which may possibly be in the Cambrian is very micaceous and sandy (Lab. No. 2017). It is sufficiently plastic to mold, but does not yield very good results on burning.

Again, 1.5 miles southwest of Culpeper, there occurs a very sticky red clay, which appears to be very abundant. The material (Lab. No. 2018) takes 40 per cent of water to work it up, but gives a mass of excellent plasticity, whose air shrinkage is 7.2 per cent. It burns red-brown, but owing to the high porosity of the burned product does not give a very hard bricklet. Thus at Cone 010 the absorption was 34.4 per cent, while even at Cone 05 the absorption was 31.7 per cent, with a fire shrinkage of 3 per cent.

The material is a low-grade brick clay.

ORANGE COUNTY.

Gordonsville.—The Catoctin formation lies to the west of the railroad and separated from it by a narrow belt of Cambrian. A sample of it was obtained about 2 miles north of west from Gordonsville on the Barboursville road, and may be residual from diabase.

This clay (Lab. No. 2035) is red, smooth, and plastic. Thirty-eight per cent water gave a mass with moldable qualities, and 7.7 per cent air shrinkage. The burned product has a red color, and is fairly hard even at Cone 010, but shows a tendency to develop many small surface cracks. The absorption after burning is also high. Thus at Cone 010 the fire shrinkage and absorption were, respectively, 4.3 and 30.8 per cent, while at Cone 05 they were 6.4 and 27.7 per cent.

The material could be used for common brick, but is not the best obtainable.

SUMMARY OF TESTS OF ALGONKIAN (CATOOTIN SCHIST) CLAYS.

Laboratory No.	LOCALITY	Water required for mixing	Plasticity	Air shrinkage	Tensile strength, lbs. per sq. in.	Cone 010		Cone 05		Cone 03		Cone 1	
						Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption
		Per Cent		Per Cent		Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
2019	Warrenton	37.0	Not	6.4	71.0	2.3	27.0	3.0	23.5	6.0	18.1	4.4	17.7
2025	Warrenton	50.0	High	5.6	.....	3.4	30.0	.....	.....	.....	.....	.....	.....
2014	Culpeper	38.0	Fair	5.6	.....	0.0	27.8	.....	.....	.....	.....	.....	.....
2015	Culpeper	22.0	Fair	4.5	.....	0.0	18.5	0.0	15.3	.....	.....	.....	.....
2016	Culpeper	34.0	Fair	7.5	.....	2.4	40.0	3.7	36.0	.....	.....	.....	.....
2017	Culpeper	36.0	Fair	1.6	.....	.....	.....	.....	.....	.....	.....	.....	.....
2018	Culpeper	40.0	Good	7.2	.....	0.0	34.4	3.0	31.7	.....	.....	.....	.....
2035	Gordonsville	38.0	Fair	7.7	.....	4.3	30.8	6.4	27.7	.....	.....	.....	.....

COMMENTS ON THE TABLE.

The chief features of these clays are the high amount of water required for molding, and their high absorption after burning. They can be used for brick-making, but most of them are too open burning, and if possible a clay that fires to a denser body should be chosen. No. 2015 from Culpeper forms a desirable exception.

PRE-CAMBRIAN VOLCANIC CLAYS.

These occupy a small area in the southern part of the Piedmont region, extending from north of Meherrin southwest to Virgilina. The rocks are more or less schistose, and weather to a ferruginous residual clay, which is often suitable for brick manufacture.

CHARLOTTE COUNTY.

Keysville.—There are not many exposures of clay in the pre-Cambrian volcanic area around Keysville, although where any are seen the material seems to be fairly plastic, but not over 3 or 4 feet deep.

LUNENBURG COUNTY.

Simplicity.—This town lies between Keysville and Meherrin, and in the Virginian Railroad cut at Simplicity station, the pre-Cambrian volcanics yield a residual clay from 3 to 4 feet deep. This is one of the few localities where a sample of this formation was obtainable.

The clay (Lab. No. 2062) is red, smooth, moderately plastic, working up with 41 per cent of water to a mass whose air shrinkage was 9.2 per cent. The clay burns red, with a good ring even at Cone 010, and is a good brick clay, even though the absorption of the bricklets is a little high. At Cone 010 the fire shrinkage was 3 per cent, and absorption 26.8 per cent. At Cone 05 the fire shrinkage was 2.7 per cent, with an absorption of 26 per cent. The bricklets were steel hard even at Cone 010.

Virso.—In this vicinity, too, we were able to obtain samples of the residuals of the pre-Cambrian volcanics. One of these was obtained from a cut a third of a mile west of Virso on the Virginian Railroad, the section being about 25 feet high. The bedrock is a light-colored schist, and the passage from bedrock to clay is rather abrupt.

The clay (Lab. No. 2048) is very smooth and plastic, and works up with 23 per cent of water to a body having 7.4 per cent air shrinkage. It burns to an excellent hard body, of low fire shrinkage, although not very

bright color, at Cone 010. The absorption, moreover, is not by any means high, so that the material recommends itself as a brick clay, or possibly even for other kinds of structural clay products. At Cone 010 the fire shrinkage and absorption were 0.3 per cent and 12 per cent, respectively, while at Cone 05 they were 1 per cent and 9 per cent.

Just west of Virso on the same railroad is a cut about 200 feet long and 12 feet high, showing a very uniform clay of gneissic texture, and bands of deep red and yellow. This material is very gritty, smooth, and sticky. Two samples were collected, one of these (Lab. No. 2041) representing the upper six feet, and the other (Lab. No. 2046) representing the bottom six feet. A comparison of the two is interesting, as it indicates how the upper and lower portions of a deposit may differ, and, consequently, in order to get an average sample, it should not be taken from too shallow a depth.

Sample No. 2041 is a red, fairly smooth, plastic clay, which absorbs a large amount of water in mixing, namely, 45 per cent, and has a high air shrinkage of 10 per cent. It burns to a red body of high absorption, but good ring, even at Cone 010, and is even steel hard at this cone. At Cone 010 the fire shrinkage and absorption were 0 and 26.7 per cent, respectively, while at Cone 05 they were 3 and 25.4 per cent. The material could be used for brick manufacture, but the high air shrinkage and high absorption are not altogether desirable. These troubles might be overcome by mixing with a material like No. 2048 (p. 43).

No. 2046 shows an interesting contrast with the preceding one (No. 2041). Its air shrinkage is about the same, but the fire shrinkage is higher and absorption lower, so that it forms a good material to mix with the upper six feet of the section.

As to its qualities, the clay is smooth, fairly plastic, requires 42 per cent of water for mixing, and has an average air shrinkage of 10.3 per cent. It burns to a good red color and has a good ring, becoming steel hard at Cone 05. At Cone 010 the fire shrinkage was 2.7 per cent, and absorption 14.4 per cent. At Cone 05 the fire shrinkage was 3.7 per cent, and absorption 11.9 per cent.

The material is a good brick clay.

HALIFAX COUNTY.

Virgilina.—The testing of this clay (Lab. No. 2058) was in the nature of an experiment, as there was some doubt as to whether it would work at

all. The pyroclastic rocks exposed in the railway cut just west of the station are only partially altered, so that no bed of true residual clay is present. But the altered rock is soft and easily ground up.

It gave a mass of very fair plasticity that required 27 per cent of water for tempering, and had an air shrinkage of 1.9 per cent. The tensile strength was low, not exceeding 15 pounds per square inch.

The soft-mud bricklets gave the following results:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	0.0	24.2
05	0.0	23.2
03	1.6	23.2
1	1.6	21.5

The absorption is high, and the product is not very good unless burned to Cone 03. The material could be used, but the addition of a little more plastic clay would greatly improve it.

SUMMARY OF TESTS OF PRE-CAMBRIAN VOLCANIC CLAYS.

Laboratory No.	Locality	Water required for mixing		Plasticity	Air shrinkage		Tensile strength lbs. per sq. in.	Cone 010		Cone 05		Cone 03		Cone 1	
		Per Cent			Per Cent			Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption
								Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
2002	Mimblectly	41.0	Fair	9.2	.....	.....	.....	3.0	26.8	2.7	26.0	.....	.....	.....	.....
2004	Virgo	23.0	(Good)	7.4	.....	.....	.....	0.3	12.0	1.0	9.0	.....	.....	.....	.....
2041	Virgo	45.0	(Good)	10.0	.....	.....	.....	0.0	26.7	3.0	25.4	.....	.....	.....	.....
2045	Virgo	42.0	(Good)	10.3	.....	.....	Not over	2.7	14.4	3.7	11.9	.....	.....	.....	.....
2058	Virginia	27.4	Fair	1.9	15.0	.....	.....	0.0	24.2	0.0	23.2	1.6	23.2	1.6	21.5

COMMENTS ON THE TABLE.

The clays derived from the pre-Cambrian volcanic rocks are better than those derived from the Catoctin schist (altered basalt), and there is no reason why, so far as their properties are concerned, they should not be used in the manufacture of common brick.

PRE-CAMBRIAN GRANITE AND GRANITE-GNEISS CLAYS.

The rocks of this subdivision of the pre-Cambrian underlie two belts in the Piedmont area, and extend all the way across the State in a northeast-southwest direction.

The first or eastern belt is narrow at its upper end but widens rapidly southward, attaining its greatest width on the North Carolina boundary. Beginning at the north end and going south we find that it includes part or all of the following counties: Fairfax, Prince William, Stafford, Spottsylvania, Louisa, Caroline, Hanover, Goochland, Cumberland, Chesterfield, Amelia, Nottoway, Dinwiddie, Lunenburg, Mecklenburg, Brunswick, and Greenville. This belt is traversed by a number of lines of railway.

The second or western belt passes through Loudoun, Fauquier, Rappahannock, Culpeper, Madison, Greene, Albemarle, Nelson, Amherst, Bedford, Floyd, and Carroll. The Southern Railway skirts the southeastern edge along its middle third. It is also crossed by railroads between Leesburg and Bluemont; Manassas and Front Royal; Charlottesville and Basic; Lynchburg and Roanoke; and Rocky Mount and Roanoke. On the whole, however, this belt is not as widely accessible by lines of railway as the eastern one.

Since then the pre-Cambrian granite and granite-gneiss group covers such a large portion of the Piedmont region in Virginia, it deserves careful consideration as a possible source of clay suitable for the manufacture of clay products. Samples for testing were, therefore, collected at a number of different points, which are referred to below.

PRE-CAMBRIAN GRANITE CLAYS.**SPOTTSVYLVANIA COUNTY.**

Fredericksburg.—No brickyards are in operation at Fredericksburg. The local granite is covered by residual clay, but the exposures do not show an abundance of the material. Two samples were taken from the clay overlying the granite in the quarries west of Fredericksburg, to obtain a clue to their properties. The one (Lab. No. 2032) was too sandy to work.

The other (Lab. No. 2033) was sufficiently plastic to mold, but dried to a rather tender bricklet. This burned red, but was not very hard and showed considerable mica. The absorption was also high, being 26.4 and 22.6 per cent at cones 010 and 05, respectively.

GOOCHLAND COUNTY.

Goochland.—The residual clay from the pre-Cambrian granite and gneiss is well represented by a large cut bank, a quarter of a mile north of Maidens Station on the Chesapeake and Ohio Railroad.

In the field the clay shows the foliated structure of the rock from which it was derived, but is easily dug.

The material (Lab. No. 2140) is a micaceous clay of fair plasticity, which required 46 per cent of water for tempering. The air shrinkage was 7.3 per cent, and the average tensile strength not over 20 pounds per square inch. The bricklets made from this clay burned to a good red color, with a fair ring at Cone 05, and a good ring at Cone 03. They became steel hard at Cone 1. The other fire tests on the soft-mud bricklets are as below.

Cone	Fire shrinkage Per cent	Absorption Per cent
010	1.3	28.4
05	2.0	26.3
03	2.3	26.0
1	5.0	22.6

This clay could be used for common brick, but its absorption is a little high.

CUMBERLAND COUNTY.

Cumberland Courthouse.—On the road to Cumberland, from Farmville, there is much clay exposed in cuts as far as George (3 miles from Farmville). It is all quite sticky, and seems to be derived from a gneissic or schistose phase of the granite.

The following sample (Lab. No. 2044) is fairly typical of these exposures. It is red, sandy, not very plastic, micaceous clay, requiring 33 per cent of water for mixing, and having 7.8 per cent air shrinkage. The fire shrinkage at both cones 010 and 05 was .4 per cent, and the absorption was 24 per cent in each case. The bricklets were red and had a fair ring at the cones mentioned. The clay could be used for common brick, even though it does not burn very dense.

There is also a fair amount of red clay around Cumberland, but it varies somewhat in its character, depending on the nature of the bedrock.



(A) Pipe works at Pamplin.



(B) Kiln at Stevensburg brick plant.

The following tests made on a sample from a large bank near town are perhaps a little better than the average of this district. Like the preceding, this material (Lab. No. 2051) is also a red, sandy, micaceous clay of not very high plasticity. It took 34 per cent of water for mixing, had an air shrinkage of 6.1 per cent, and an average tensile strength of 85 pounds per square inch. The clay burns to a good bricklet of red color and having a good ring, even though the absorption is not very low.

Soft-mud bricklets yielded the following shrinkage and absorption tests:

Cone	Fire shrinkage Per cent	Absorption Per cent
010	1.0	24.7
05	2.0	23.7
03	2.7	20.5
1	3.7	18.4

This material could be used for brick manufacture.

POWHATAN COUNTY.

Ballsville.—The residual clay from the pre-Cambrian granite is exposed in a 4-foot depth of cut, just east of the station on the Tidewater and Western Railroad.

The clay (Lab. No. 2209) is red, somewhat coarse-grained due to mica and sand, but it has good plasticity. It required 28 per cent of water to temper it, and the air shrinkage was 4.7 per cent. At Cone 010 the fire shrinkage was .7 per cent, and the absorption 24.8 per cent, while at Cone 05 there was little difference in either the shrinkage or the absorption.

The bricklets though of good color are not sufficiently hard even at Cone 05 to make a first-class product.

Powhatan.—A fair amount of clay is to be seen in the cuts of the Tidewater and Western Railroad in Powhatan County, and, while the sections are not very deep, the decay of the rock seems to be fairly thorough. The soil is red and sticky.

One sample taken from a cut just west of Powhatan Station may be taken as fairly typical of many of the exposures. The material (Lab. No. 2210) is a red sandy clay of slight plasticity, working up with 27 per cent of water, and having 4.2 per cent air shrinkage. The clay when burned to the temperature usually reached in common-brick kilns makes a nice-looking bricklet, but not a very hard nor a very dense one. It could be used for small buildings. At Cone 010 the fire shrinkage and absorption were 1 and 26.5 per cent, respectively, while at Cone 05 they were 1.4 and 27.0 per cent.

Moseleys.—One-half mile east of Moseleys are several fair-sized cuts on the line of the Southern Railway. There are no rock exposures, and there is some doubt as to whether the material is derived from the pre-Cambrian granite or Triassic formations. Much of the clay is yellowish-brown, with streaks of very plastic gray clay running through it. The material is red-burning and capable of making a good common brick.

Michaux.—Here again the residual clay from the pre-Cambrian granite is obtainable, and there is at least one good section, 200 by 10 feet, exposed. The material (Lab. No. 2200) is a red sandy clay of fair plasticity, having 5 per cent air shrinkage when worked up with 32 per cent of water. It burned to a red bricklet of good appearance, but not great hardness. The fire shrinkage at both cones 010 and 05 was zero, and the absorption about 26 per cent.

Jefferson.—This is the only locality in Virginia where local clay is used exclusively for smoking-pipe manufacture. The deposit, which is probably of residual nature, lies near a stream about $1\frac{1}{4}$ miles east of Jefferson. The clay is yellow and plastic. It is strained through cloth into wooden tanks and allowed to settle. After drawing off the excess of water, it is mixed in a blunger, and tempered in a vertical pugmill. As the bar of clay issues from the mill, pieces are broken off and formed into pipes in the press. The latter are burned in a small kiln.

The two following sets of tests indicate the character of No. 2139 the crude clay, and No. 2077 the strained clay:

The crude clay is smooth and highly plastic. With 31 per cent of water it molds up well, and has 7.5 per cent air shrinkage. In burning it yielded a nice red body, with good ring and moderate absorption. As compared with the other residual clays from the pre-Cambrian granites and gneisses, it is much finer-grained, more plastic, and denser burning. At Cone 010 the fire shrinkage was 1 per cent, and absorption 19.1 per cent. At Cone 05 these figures were 2.7 and 16 per cent, respectively.

The washed clay is very smooth and plastic, and worked up with 40 per cent, the bricklets made from this showing 7.9 per cent air shrinkage. The clay burns to a nice red, smooth body, with a good ring, and steel hard at Cone 05. At Cone 010 the fire shrinkage was 0 per cent, and absorption 27 per cent, while at Cone 05 they were 3 and 20.5 per cent, respectively.

Clayville.—A brick and tile works was in operation at this locality from 1892 to 1907, and produced common, ornamental, and fire brick. The clay

supply, which was not properly prospected beforehand, gave out, and for several years clay was shipped in from other points.

NOTTOWAY COUNTY.

Nottoway.—The residual clay around Nottoway is all red, fairly plastic, and contains a moderate number of feldspar-quartz stringers, which would have to be crushed before running the clay through a brick machine.

The following sample taken from a large road cut illustrates the character of the material around Nottoway. The clay (Lab. No. 2204) is red, somewhat coarse-grained, micaceous, and of good plasticity, working up with 36 per cent of water to a mass whose air shrinkage was 7.2 per cent, and average tensile strength 75 pounds per square inch.

It makes a fair common brick, and one which is not as absorbent as many of the others from this region. It could probably be worked in a stiff-mud machine, although we did not have a sufficiently large sample to try it.

The fire tests on the bricklets were as follows:

Cone	Fire shrinkage Per cent	Absorption Per cent
010	1.3	23.0
05	1.3	21.9
03	4.0	18.3
1	4.3	17.1

Burkeville.—One-third mile east of the Norfolk and Western Railway station is a cut a third of a mile long and 15 feet deep. It consists mostly of a yellow to brown decomposed granite, with streaks and patches of red.

At the eastern end of the cut is a disintegrated white granite with pegmatite stringers, while at the western end of the cut is another patch of the same material (Lab. No. 2207). This residual clay is very sandy, of low plasticity, and air shrinkage of 1 per cent. It burns buff, and requires too high firing to make it of use for commercial brick. It might do for the boiler-setting brick.

Just east of the station on the Norfolk and Western Railway there is a cut about 175 feet long and 8 feet high, consisting of yellowish-brown clay with light streaks. The material (Lab. No. 2049) is of good plasticity, and works up with 27 per cent water. It had an air shrinkage of 5.8 per cent, and average tensile strength of 81 pounds per square inch.

The soft-mud bricklets burned to a buff body, but one that flashed rather easily in the firing, and if fired to Cone 03 had a good ring, although

a product was obtained at Cone 05 that would probably be salable. On firing the soft-mud bricklets showed the following additional properties:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	.0	20.4
05	.1	20.4
03	.2	15.8
1	1.7	16.4

This clay should make a good common brick by the soft-mud process. A sample was also put through the stiff-mud machine, and flowed through the brick die without any difficulty. Another sample was molded into dry press, but did not give a sound bricklet under Cone 1. This clay is unlike most of the other residuals from this formation in its color-burning qualities, for it yields a buff product.

At High Bridge on the Norfolk and Western Railway there is another cut containing decomposed pegmatite, in fact considerable clay is exposed in the cuts here.

Blackstone.—There are no exposures of clay on the road west of Blackstone, but in a cut on the Norfolk and Western Railway, just east of the freight depot, a good section in the residual clay is to be seen. The deposit is at least 12 feet thick, and seems to be quite uniform in character.

The clay (Lab. No. 2011) is slightly sandy, but of good plasticity. With 29 per cent of water it gave a nice moldable mass. The air shrinkage was 7.5 per cent, and the average tensile strength 77 pounds per square inch. It burns red, and gives a good sound product at Cone 03, and even a fair one at Cone 05.

The firing tests of the soft-mud bricklets were:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	0.0	20.8
05	1.0	19.0
03	1.4	17.0
1	2.5	15.34

A second lot of the clay was tested out in the stiff-mud machine. It worked finely in the brick die, and also fairly well in the hollow-brick die. The clay would make a good red brick, and could probably be used also for hollow brick.

(One-half mile west of Blackstone is the brickyard of Adams and Cannon, not now in operation. The clay is fairly plastic, red, and full of quartz stringers. The bricks that were made from it are rather soft.

The air shrinkage of this clay (Lab. No. 2208) is 3.7 per cent, rather characteristic of a sandy clay. While the bricklets made from this clay burned to a good red color, they would have to be fired above Cone 05 to make a salable product. The fire shrinkage up to this cone is zero, and the absorption 23 per cent.

If a more plastic clay were added, it would give a better product.

DINWIDDIE COUNTY.

Dinwiddie.—For at least a quarter of a mile west of the station there are several good cuts, some of them 10 feet deep. The material in all is residual clay from a coarse-grained granite, and that described below (Lab. No. 2061), shows the character of the clay.

It is micaceous gritty clay of good plasticity. Water required for mixing, 31 per cent; air shrinkage, 5.3 per cent; average tensile strength, 68 pounds per square inch. The material burns to a reddish-buff bricklet, and while the working qualities are good, and the absorption not excessive, it has to be well burned to give a good ringing brick.

The soft-mud bricklets gave the following results:

Cone	Fire shrinkage Per cent	Absorption Per cent
010	.4	22.2
05	.7	21.6
03	3.0	18.0
1	3.0	19.6

A sample of the clay worked in the stiff-mud machine without any difficulty, and gave a fair brick.

LUNENBURG COUNTY.

Kenbridge.—The bedrock around Kenbridge appears to be a complex of chiefly gneisses, schists, and granites, but exposures of the fresh rock are rare. The clays are all shades of red, yellow, gray, greenish-gray, and white. They range from plastic to lean and sandy.

A brickyard was formerly located on the site of the present Kenbridge roller mill, but the bricks to be seen in some of the buildings did not appear to be very uniform.

A sample, representing average material, was taken from a cut 300 feet in length just east of the station. The material (Lab. No. 2010) represents a red sandy clay of good plasticity. It worked up with 33 per cent of water, the bricklets made from this having 7.5 per cent air shrinkage, and

125 pounds per square inch tensile strength. The clay burns red, and gives a very fair brick even at Cone 010. The soft-mud bricklets also gave the following additional data after firing:

Cone	Fire shrinkage Per cent	Absorption Per cent
010	.7	22.5
05	.7	20.0
03	3.0	18.7
1	3.7	16.79

Another sample was run through the stiff-mud machine. It flowed readily through the brick die, but the whitish lumps in the clay did not pug up very easily. This clay seems well adapted for making building brick. If burned hard enough it might be possible to make a dry-press brick from the material.

Victoria.—A mile or so east of the railroad station is a long cut of whitish residual clay. No sample of it is available for testing, but it may be buff-burning.

Meherrin.—A fine cut of residual clay, 18 feet deep and about half a mile long, is to be seen on the Virginian Railway west of Meherrin Station. The clay is red, fairly sticky, and not always very deep, but the rock below it is badly rotted.

The material (Lab. No. 2089), which is noticeably micaceous, worked up with 43 per cent of water to a mass of good plasticity, with 9.1 per cent air shrinkage, and 86 pounds per square inch tensile strength. The bricklets burned at Cone 010 had a good red color and fair ring, and the same held true at Cone 05, but at Cone 03 there was an appreciable increase in the fire shrinkage, at which cone the bricklets also became steel hard.

Other fire tests on the wet-molded bricklets were:

Cone	Fire shrinkage Per cent	Absorption Per cent
010	0.0	28.9
05	1.0	27.9
03	3.6	16.2

The absorption is somewhat high, but otherwise the product is good. The clay was also found to work in the stiff-mud machine.

At one point in the cut above mentioned, about 250 yards from the railway station, the clay is light-colored, plastic, and badly stained with iron and some black-staining matter.

In a small sample the clay (Lab. No. 2042) looks as if it might have been derived from a pegmatite, because of its cream color. It is smooth and of good plasticity. After mixing with 26 per cent of water it had 8.3 per cent air shrinkage. The clay burned to a nice red bricklet, with good ring at Cone 010, and the absorption was lower than is usually found in these residuals. At Cone 010 the fire shrinkage was .7 per cent, and absorption 14.9 per cent, while at Cone 05 they were 1.7 per cent, and 12.7 per cent, respectively. The clay would probably work in a stiff-mud machine. It is a good red brick clay, and might also serve for making hollow blocks.

MECKLENBURG COUNTY.

Lacrosse.—There are but few cuts around Lacrosse, hence it is difficult to estimate the amount of clay in this vicinity. Where any clay is exposed it is mostly red, but covered with a surface soil of yellow or gray color.

The following sample (Lab. No. 2070) is fairly typical of the residual clay in this vicinity, and was collected from a road cut near the high school. The tests showed it to be a red clay of good plasticity. Its air shrinkage after mixing with 46 per cent of water was 8.8 per cent, which is a little high, and the average tensile strength 86 pounds per square inch. It burns to a red color, and has a fair ring even at 010.

The other tests on the soft-mud bricklets were:

Cone	Fire shrinkage Per cent	Absorption Per cent
010	2.4	27.2
05	4.0	24.2
03	8.0	13.9
1	8.6	13.5

The material should make a good common brick, burning hard at a low cone. It does not work very well dry press, but might run satisfactorily through a stiff-mud die.

Clarksville.—Immediately around Clarksville, especially on the south, there is much red clay exposed in gullies and shallow road cuts, the bedrock in places being schistose, in others gneissic, or even in some places massive in structure.

As a type of the clay derived probably from schist, reference may be made to the old road cut, a third of a mile south of town, and south of the Petersburg road, as well as 100 yards north of the bridge. The material (Lab. No. 2066) is a smooth red clay of good plasticity. The trial bricklets had 6.2 per cent air shrinkage when mixed with 31 per cent water.

They burned to a red color, and good ring even at Cone 010, and became steel hard at Cone 05. The fire shrinkage and absorption at Cone 010 were 2.3 and 25.4 per cent, respectively, while at Cone 05 they were 3 and 22.4 per cent, respectively. From these few preliminary tests the material gives promise of making good common brick.

A deposit, derived from more gneissic rock, is to be seen in a cut on the Petersburg road, 150 feet south of the bridge, and about half a mile south of town, the cut being 100 by 7 feet, and the clay extending nearly to the bottom of the cut.

This clay (Lab. No. 2065) is red like the preceding, but quite sandy and not as plastic, although there was no trouble in molding it. After mixing with 27 per cent of water it showed an air shrinkage of 6.3 per cent. The clay burns red, and has a fair ring even at Cone 010, although of high absorption. At Cone 010 the fire shrinkage was zero, and absorption 33.4 per cent, while at Cone 05 the fire shrinkage was 1 per cent, and absorption 21.8 per cent. The clay could be used for brickmaking.

Just at the edge of town, on the same road, is a bank 175 by 10 feet composed of clay derived from a coarse-grained gneiss or granite, and so quartzose as to be very deceptive as to its plasticity. The material (Lab. No. 2071) is a yellowish-brown, very sandy clay, of moderate plasticity. The bricklets made from the clay when mixed with 30 per cent water had an air shrinkage of 5 per cent, and were not very hard. They burned to a red brick, but the product was not very hard even though the absorption was moderate. The fire shrinkage and absorption at Cone 010 were zero and 19.5 per cent, respectively, and at Cone 05 they were practically the same.

Judging from this sample, the material is not a very good brick clay.

To the east of Clarksville on the National Highway is a red plastic clay, occurring in considerable quantity in shallow cuts, but with no exposure of bedrock. Here, again, we have a red smooth clay (Lab. No. 2031) of good plasticity. With 29 per cent of water it worked up to a mass having 7.4 per cent air shrinkage, and 68 pounds per square inch tensile strength.

The soft-mud bricklets burned red and had a good ring even at Cone 010. They became steel hard at Cone 05, but if burned to Cone 1, while hard and sound, the color became too dark.

Other tests on these soft-mud bricklets are as below:

Cone	Fire shrinkage Per cent	Absorption Per cent
010	1.3	20.1
05	1.7	12.4
1	4.3	14.4



(A) Residual clay near Lawrenceville.



(B) Residual clay near Alberta.

The clay also worked fairly well in the brick die of the stiff-mud machine, but showed a tendency to tear in the hollow-brick die. This may possibly have been the fault of the die. There seems no reason why this material should not be used to make a good grade of brick.

Boydton.—Residual clay from granite is well exposed on the National Highway, 1 mile west of Boydton, the bank being about 250 by 9 feet. This represents a type which is plentiful in this area, being noticeable in cuts all the way from Boydton to Clarksville.

A sample was tested from the large bank near Boydton, with the following results: The material (Lab. No. 2088) is a red smooth clay of good plasticity. It required 42 per cent of water to work it up, and the bricklets made from the clay had an air shrinkage of 7.9 per cent, and an average tensile strength of 48 pounds per square inch. The clay burned to a good red color, with a fair ring at Cone 010, and an excellent ring at Cone 03, at which temperature they were steel hard.

The fire shrinkage and absorption were as follows:

Cone	Fire shrinkage Per cent	Absorption Per cent
010	.4	32.
05	.4	31.8
03	3.3	22.2
1	4.0	23.6

The clay would probably work in a stiff-mud machine. There seems no obstacle to using this clay for the manufacture of good common brick. It is not to be recommended for a dry-press product.

BRUNSWICK COUNTY.

Alberta.—Several good cuts of residual clay occur along both the Seaboard Air-Line and the Virginian railways near Alberta. The best one is just east of Alberta on the Seaboard Air-Line Railway. Here in a cut about 300 by 10 feet is a mass of light gray, yellow, and red clay, with many small stringers of decomposed pegmatite.

This bank was sampled to include all except the top foot, and gave very satisfactory results on testing. The clay (Lab. No. 2028) is somewhat gritty and of moderate plasticity. Its air shrinkage when mixed with 32 per cent of water was 7.1 per cent, and the average tensile strength 70 pounds per square inch. It burns to a reddish-brown color, and gives a good brick at Cone 05, but is a little too soft at Cone 010. The absorption is moderate. The soft-mud bricklets behaved as follows:

Cone	Fire shrinkage Per cent	Absorption Per cent
010	.0	21.6
05	1.3	21.1
03	4.7	14.8
1	4.6	14.1

Although the clay is sandy, it flowed through the brick die of the stiff-mud machine without difficulty. The tests indicate the probability of making brick from this clay by either the soft-mud or stiff-mud process. It did not work well dry press.

Cochran.—Just west of the railroad station is a cut, 250 to 300 feet long and 15 feet deep, showing a fine exposure of red plastic clay to its full depth. No test was made of it, but the material would probably work for brick.

Lawrenceville.—In the vicinity of Lawrenceville there are a moderate number of cuts, showing red residual clay. On the northern edge of town, along the Cochran road, is a bank about 150 by 10 feet, showing red clay, rather typical of this vicinity.

The clay (Lab. No. 2060), although containing considerable finely divided mica, had fair plasticity. With 40 per cent water it gave a workable mass whose air shrinkage was 5.8 per cent, but whose average tensile strength was low, not exceeding 15 pounds per square inch. To give a good product it should be burned to at least Cone 05 and preferably Cone 03. The color after burning is red, and the bricklets at Cone 03 were steel hard.

Cone	Fire shrinkage Per cent	Absorption Per cent
010	1.0	31.2
05	2.3	30.3
03	4.0	22.0
1	4.0	22.6

It worked well in the brick die of the stiff-mud machine, and even flowed pretty well through the hollow-brick die.

There is no reason why this clay could not be used to advantage in the manufacture of good common brick, and it might even serve for making hollow brick.

Brodnax.—Several good cuts of red clay are to be found along the railroad between Brodnax and Lawrenceville.

ALBEMARLE COUNTY.

Crozet.—The country both north and south of Crozet, for a reasonable distance from the railroad, was looked over in search for good clay. A number of exposures were found, but, as will be seen from the tests noted below, the deposits were not of equal value. Just north of Brownsville, which is south of Crozet, a yellowish-brown clay, with scattered rock fragments, is to be seen.

This material (Lab. No. 2078) is of fair plasticity, and worked up with 33 per cent of water to a mass whose air shrinkage was 5.4 per cent, and average tensile strength 59 pounds per square inch. The clay burns red, is steel hard at Cone 03, but has a fair ring at Cone 010.

Further tests are as below:

Cone	Fire shrinkage Per cent	Absorption Per cent
010	.0	23.7
05	.7	21.9
03	2.7	19.3
1	3.0	18.4

This clay should make a good common brick by the soft-mud process, and could probably be worked also in the stiff-mud machine.

A little farther north residual clay outcrops again (Lab. No. 2076). This is a brown, plastic, smooth clay, which burns red, and has a low air shrinkage, but does not give a sufficiently hard brick at Cone 010. It should be burned to Cone 05 for good results.

Along the road up to half a mile north of Crozet Station there are several cuts showing very consistent and homogeneous clay, and one sample (Lab. No. 2055) taken from a point a quarter of a mile north of the railroad is quite typical. This red-brown clay has good plasticity. With 31 per cent of water it developed a workable body for soft-mud molding. The air shrinkage is 5.2 per cent, but the average tensile strength is not over 15 pounds per square inch. It burns to a red bricklet, steel hard at Cone 03, but not sound enough unless fired to Cone 05.

Further tests on the soft-mud bricklets are tabulated below:

Cone	Fire shrinkage Per cent	Absorption Per cent
010	.3	25.1
05	2.7	23.0
03	4.7	16.8
1	4.7	17.3

The clay will flow through the brick die of the stiff-mud machine, but care had to be used to prevent the bar from tearing as it issued from the die. It did not work dry press. This material can be used for making common brick if properly fired. It would work in a soft-mud machine, and might work in a stiff-mud one.

NELSON COUNTY.

Roseland.^a—This district contains: (1) Red residual clay derived from gabbro, quartz monzonite, and the hornblende phase of the rutile-bearing syenite, and (2) kaolin or white residual clay derived from the purer feldspathic phase of the syenite. The latter is discussed under the kaolins. The other group is referred to here.

Near the mine of the American Rutile Company there is considerable residual clay derived from the quartz-bearing syenite. The material (Lab. No. 2185) is red-brown, smooth, and contains scattered grains of blue quartz, which does not break down on weathering. With 35 per cent water it works up to a mass of good plasticity, and has 8.4 per cent air shrinkage. The clay burns red, has a good ring at Cone 010, and is steel hard at Cone 05. At Cone 010 the fire shrinkage and absorption were 2.4 and 26.9 per cent, respectively, while at Cone 05 they were practically the same.

There is no reason why this clay should not be used for making common brick, if molded in a soft-mud machine, and, while it would probably flow through the die of a stiff-mud machine, the many small quartz fragments would interfere with the cutting wires.

In this same district there is a variable amount of residual clay derived from the quartz-monzonite, but there are few good sections in it and most of these show a somewhat sandy clay. Near Colleen, about 1,000 yards south of it, on the Roseland-Arrington Highway, there is a deposit of clay which is evidently washed from the quartz monzonite residuals. Although sandy, the material (Lab. No. 2170) is plastic and of low air shrinkage. It burns buff at both cones 010 and 05, with about 14 per cent absorption.

AMHERST COUNTY.

Amherst.—The region around Amherst is underlain by quartz-monzonite gneiss, which varies in places both structurally and in mineral composition. Hence with variation in the character of the underlying

^a For a detailed discussion of the geology of this district, see Watson and Taber, Bull. III-A, Va. Geol. Survey, 1913.

rock there will be more or less variation in character of the residual clay derived from it, aside from differences due to the stage of decay of the material.

The clays around Amherst seem to be rather irregular in depth, and the more schistose phase of the quartz-monzonite seems to weather more readily to clay than the coarser-grained, normal rock. Several cases may be quoted to show the character of the clays obtainable around Amherst.

On Buffalo Hill, about 2 miles north of Amherst, there occurs rather an extensive exposure of tough clay (Lab. No. 2093), which appears to be of promising character. It is a smooth red clay of good plasticity. If mixed up with 31 per cent water the bricklets molded therefrom had an air shrinkage of 6.9 per cent, and an average tensile strength of 67 pounds per square inch.

These wet-molded bricklets burn to a good red color up to Cone 05, but to a considerably darker color above this. They were steel hard at Cone 1, and had a fair ring at Cone 05, but showed a little tendency to develop surface cracks. The other soft-mud tests are as below:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	0.0	23.1
05	.4	18.3
1	1.4	15.7

Molded in the stiff-mud machine, the clay worked well through the die if not too wet. It is probable that red brick could be made from this clay by either the soft-mud or stiff-mud process.

On the south side of Buffalo River, along the short-cut road connecting the two curves of the toll road, is a long cut of very sandy material, which is only partly decomposed (Lab. No. 2057). It is so micaceous and of such low plasticity as to be unfit for brick manufacture.

About 1 mile south of Amherst the surface clay is redder, more plastic, and more promising than the preceding. This material (Lab. No. 2074) is smooth and plastic. With 35 per cent water it gave a mass that was easily molded, and had 8.1 per cent air shrinkage.

The bricklets burned red, had a fair ring at Cone 010, and an excellent ring at Cone 05. At Cone 010 the fire shrinkage and absorption were, respectively, .6 and 30 per cent. At Cone 05 they were 2 and 28.2 per cent.

These few preliminary tests indicate that the material could serve at least as a local source of supply for the manufacture of common brick.

No bricks are made from the clays around Amherst, and, owing to the hilly nature of the country, a brick plant if started should be located fairly close to the railroad.

The buildings of Sweet Briar College are said to have been made from local clays.

BEDFORD COUNTY.

Bedford City.—Residual clays from granite occur throughout this district, but there are few good exposures in wagon or railroad cuts. One of the best is on the road to Thaxton, and just west of Bedford City, where the ferruginous clay shows in a cut about 6 feet deep.

The material (Lab. No. 2098) is a fairly plastic red clay of slightly micaceous character. Worked up with 34 per cent water it had 7.8 per cent air shrinkage. At Cone 010 the fire shrinkage and absorption were, respectively, .4 and 26.6 per cent, while at Cone 05 they were 1.4 and 23.5 per cent. The bricklets had a good ring and red color at Cone 010. From these tests we feel sure the material would work for common brick.

A mile farther west on the same road is another and larger bank, probably 15 feet high, and lying between the highway and the railroad. This is also a good red-burning clay.

Again just west of the railroad station on the north side of the track, residual clays from granite-gneiss are exposed in several cuts, but only the upper portion is decayed enough to yield a clay worth working, the lower part (Lab. No. 2096) being so sandy as to yield a soft porous brick.

Between Bedford City and Lynchburg there are a number of cuts, some like those at Lowry and Forest appearing to contain considerable clay.

SUMMARY OF TESTS OF PRE-CAMBRIAN GRANITE CLAYS.

Laboratory No.	LOCALITY	Water required for mixing		Plasticity	Air shrinkage		Tensile strength, lbs. per sq. in.		Cone 010		Cone 05		Cone 03		Cone 1	
		Per Cent			Per Cent				Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption
2032	Fredericksburg															
2033	Fredericksburg				4.9	Not over			0.0	26.4	3.6	22.6				
2140	Goochland	46.0	Only		7.3	20.0			1.3	28.4	2.0	26.3	2.3	26.0	5.0	22.6
2044	Cumberland	33.0	Fair		7.8				0.4	24.6	0.4	24.3				
2051	Cumberland	34.0			6.1	85.0			1.0	24.7	2.0	23.9	2.7	20.5	3.7	18.4
2209	Ballsville	28.0	Slight		4.7				0.7	24.8	0.6	25.3				
2210	Powhatan	27.0	Good		4.2				1.0	26.5	1.4	27.0				
2200	Michaux	32.0	Fair		5.0				0.6	26.6	0.0	27.6				
2139	Jefferson	31.0	High		7.5				1.0	19.1	2.7	16.0				
2077	Jefferson	40.0			7.9				0.0	27.0	3.0	20.5				
2204	Nottoway	36.0			7.2	75.0			1.3	23.0	1.3	21.9	4.0	18.3	4.3	17.2
2207	Burkeville	15.0	Very		1.0				0.0		1.0	15.7				
2049	Burkeville	27.0	Low		5.8	81.0			0.0	20.4	1.0	20.4	2.0	15.8	2.7	16.4
2011	Blackstone	29.0	Good		7.5	78.0			0.0	20.8	1.0	19.0	1.4	17.0	2.5	15.3
2208	Blackstone	22.0	Good		3.7				0.0	23.0	0.0	23.1				
2061	Dinwiddie	31.0	Low		5.3				0.4	22.2	0.7	21.6	3.0	18.0	3.0	19.6
2010	Kenbridge	33.0	Good		7.5	125.0			0.7	22.5	0.7	20.9	3.0	18.7	3.7	16.8
2089	Meherrin	44.0	Good		9.1	86.0			0.0	28.9	1.0	27.9	3.6	16.2		

SUMMARY OF TESTS OF PRE-CAMBRIAN GRANITE OLAYS—Continued.

Laboratory No.	LOCALITY	Water required for mixing	Plasticity	Air shrinkage Per Cent	Tensile strength, lbs. per sq. in.	Cone 010		Cone 05		Cone 03		Cone 1	
						Fire shrinkage Per Cent	Absorption Per Cent	Fire shrinkage Per Cent	Absorption Per Cent	Fire shrinkage Per Cent	Absorption Per Cent	Fire shrinkage Per Cent	Absorption Per Cent
2042	Meherrin	26.0	.....	8.3	.....	0.7	14.9	1.7	12.7	.....	.....	.....	.....
2070	Lacrosse	46.0	.....	8.8	86.0	2.4	27.2	4.0	24.2	8.0	13.9	8.6	13.5
2066	Clarksville	31.0	Good	6.2	.....	2.3	25.4	3.0	22.4	.....	.....	.....	.....
2065	Clarksville	27.0	.....	6.3	.....	0.0	33.4	1.0	21.8	.....	.....	.....	.....
2071	Clarksville	30.0	.....	5.0	.....	0.0	18.6	0.6	19.5	.....	.....	.....	.....
2031	Clarksville	29.0	Good	7.4	69.0	1.3	20.1	1.7	18.4	.....	.....	4.3	14.4
2088	Boynton	42.0	Good	7.9	48.0	0.4	32.0	0.4	31.8	3.3	22.2	4.0	23.6
2028	Alberta	32.0	Mod- erate	7.1	70.0	0.0	21.6	1.3	21.1	4.7	14.8	4.6	14.1
2060	Lawrenceville	40.0	Fair	5.8	15.0	1.0	31.2	2.3	30.3	4.0	22.0	4.0	22.6
2078	Crozet	33.0	Fair	5.4	60.0	0.0	23.7	0.7	21.9	2.7	19.3	3.0	18.4
2076	Crozet	30.0	.....	4.6	.....	0.4	.....	.....	.....	.....	.....	.....	.....
2055	Crozet	31.0	Good	5.2	15.0	0.3	25.1	2.7	23.0	4.7	16.8	4.7	17.3
2185	Roseland	35.0	Good	8.4	.....	2.4	26.9	2.4	26.4	.....	.....	.....	.....
2170	Colleen	20.0	Fair	2.7	.....	0.0	14.4	.....	.....	.....	.....	.....	.....
2093	Amherst	31.0	Good	6.9	67.0	0.0	23.1	0.4	18.3	.....	.....	1.4	15.7
2057	Amherst	32.0	Low	3.5	.....	.....	.....	.....	.....	.....	.....	.....	.....
2074	Amherst	35.0	.....	8.1	.....	0.6	30.0	2.0	28.2	.....	.....	.....	.....
2098	Bedford City	34.0	Mod- erate	7.8	.....	0.4	26.6	1.4	23.5	.....	.....	.....	.....
2096	Bedford City	28.0	Mod- erate	2.0	.....	.....	.....	.....	.....	.....	.....	.....	.....



(A) Residual clay near Louisa.



(B) Residual clay containing limonite near Pittsville.

COMMENTS ON THE TABLE.

The residual clays derived from the pre-Cambrian granites and gneisses are mostly of good plasticity, so that they can be molded without difficulty, some of them working well in the stiff-mud machine. They also burn to a good color. Many of them could be used for the manufacture of common brick and some of them for hollow tile.

PRE-CAMBRIAN CRYSTALLINE SCHISTS AND GNEISS CLAYS.

There is one irregular but important belt or area of rocks of this subdivision of the pre-Cambrian.

It enters the State in Fairfax County, and crosses parts of Prince William, Culpeper, Stafford, Orange, Spottsylvania, Louisa, and Fluvanna counties. It then widens out in Buckingham, Appomattox, Prince Edward, Campbell, Charlotte, Halifax, and Pittsylvania counties. A broad triangular area including parts of Grayson, Carroll, Patrick, Floyd, Henry, and Franklin counties lies on the west.

Except for the last-mentioned triangular area, the formation is traversed by a number of lines of railway, and, next to the pre-Cambrian granite belt, is the most important from standpoint of size in the Piedmont province.

LOUISA COUNTY.

Louisa.—The residual clays around Louisa are mostly red burning, although there are some exceptions.

Thus about three-quarters of a mile due northeast of Trevilians there is a deposit of whitish clay near J. L. Latham's house. A pit about 50 feet square was opened some 22 years ago, and brick made from it. The clay, which seems to occur in some quantity, is very sericitic, and contains considerable quartz. There is some doubt as to whether it is derived from a pegmatite or from a schist containing stringers of pegmatite.

As tested out in the laboratory, the material (Lab. No. 2034) was cream-colored, contained much fine grit, and was low in plasticity. Air shrinkage 4.4 per cent. Two trial burns were made on it, one at Cone 010 and the other at Cone 05. The fire shrinkage in each case was low, and the absorption about 20 per cent. At neither of these cones was the bricklet very solid.

The material does not appear to contain much iron, and, while of no value for building brick, it might if burned harder serve for boiler-setting brick.

At another point, $1\frac{3}{4}$ miles due northeast of Trevilians, there is a bank of clay 70 feet long, which appears to be derived from the weathering of granite. Several other exposures of the same material are to be found near-by, so that it is probably rather abundant. The clay (Lab. No. 2082) is a dark brown, plastic, sandy material, requiring little water to mix (24 per cent) as compared with many others. The air shrinkage was 6.2 per cent. The clay burns to a nice red color, but must be fired above Cone 05 to give a good hard brick. At this cone the absorption is 18 per cent.

A third locality is well exposed about $1\frac{1}{2}$ miles north of Louisa on the road to Ellisville. Here there is a bank about 200 feet long with a maximum depth of 8 feet. This material (Lab. No. 2087) is a red micaceous clay, containing scattered fragments of the bedrock. It has fair plasticity, and, when mixed up with 40 per cent of water, showed 7.4 per cent air shrinkage. The average tensile strength was 97 pounds per square inch. The clay burns red, and the bricklets had a fair ring even at Cone 010, although they did not become steel hard until Cone 03. At this cone also the color became appreciably darker.

Other tests on the soft-mud bricklets are given herewith:

Cone	Fire shrinkage Per cent	Absorption Per cent
010	0.0	24.4
05	1.0	22.6
03	4.0	16.0
1	4.4	16.0

This clay would make a common brick, but might not work in a stiff-mud machine. At several places on the road leading north from Louisa there is clay exposed resembling sample No. 2082, as well as material which appears to be practically identical with sample No. 2087.

Mineral.—In the region about Mineral the residual clays are mostly of red color, but there are few good exposures. Bricks were formerly made at a yard located along the railway just east of Mineral. The excavation is not over 5 feet deep, and the yard has not been in operation for several years. The clay (Lab. No. 2081) is brownish-red, of good plasticity, but contains scattered quartz fragments, which may cause trouble in molding, if not crushed. There were also scattered schist fragments in the material. The sample tested required 44 per cent of water to give a plastic mass, and gave 9.5 per cent air shrinkage. The average tensile strength was 122 pounds per square inch.

The soft-mud bricklets had a good red color, a good ring at Cone 010, and became steel hard at Cone 03, although at this heat the shrinkage had increased considerably, and the color had become very much darker. The other tests were:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	1.3	28.1
05	1.3	26.6
03	7.6	12.2
1	8.0	12.4

The sudden decrease in absorption accompanying the increased fire shrinkage is quite noticeable in the above figures. A sample was put through the stiff-mud machine, but it was difficult to make the clay run through the die without tearing unless the bar was run slowly with the minimum quantity of water in the clay. This clay should make good common brick, but the best results may be obtained by molding it in a soft-mud machine.

Along the road from Mineral to Holladay, and about 400 feet south of the crossing of the Sulphur-Mine Railroad, there is a long, but rather shallow cut in the residual clay. This is tough, somewhat stony, and requires thorough disintegration before molding.

This clay (Lab. No. 2100) is fairly plastic, but mealy to the feel. It shows an air shrinkage of 7.8 per cent, and a tensile strength of 71 pounds per square inch. The clay burns red, with a fair ring at Cone 05, but not hard enough at Cone 010. It was steel hard at Cone 03.

The fire tests on the soft-mud bricklets gave the following results:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	0.0	23.0
05	.7	22.1
03	3.0	16.4
1	4.0	16.3

There is no reason why this clay should not make a red brick by the soft-mud process. A sample was tried in the stiff-mud machine, but, in spite of the plastic nature of the material, it would not flow through the die without tearing. Possibly it might work in some other style of die.

APPOMATTOX COUNTY.

Appomattox.—The bedrock around Appomattox is a micaceous schist, with many stringers of quartz up to 1 inch in thickness. So far as could be determined from surface evidence, the clay derived from the schist does

not seem to be very abundant, and in some places the bedrock comes close to the surface. The following sample (Lab. No. 2079) may serve to show the character of the clay derived from the schist.

The material is a dark red, micaceous, sandy clay of good plasticity. It had 7.9 per cent air shrinkage, and the bricklets burned at Cone 010 had a good red color, and good ring. At Cone 010 the fire shrinkage and absorption were, respectively, .3 and 27.1 per cent, while at Cone 05 they were 2 and 25 per cent.

The clay should be well adapted to common-brick manufacture.

Pamplin.—Located at Pamplin is a small plant of the Akron Pipe Company, which is making clay-pipe bowls. Two clays are used. One is a light gray clay from Ohio. The other is a yellow clay, of red-burning character, obtained from Stony Point on James River. Some clay has also been obtained from the farm of R. Davis, near Pamplin. This material while used in pipe making also seems to be adapted to other uses.

It is a very smooth and plastic clay (Lab. No. 2030), in fact it is one of the best residual clays of the Piedmont. With 23 per cent of water the mixture had an air shrinkage of 5.3 per cent, burned to a bright red color, and had an excellent ring even at Cone 010, as well as being steel hard. It also gave a product of low absorption with low fire shrinkage. At Cone 010 the fire shrinkage and absorption were, respectively, .4 and 12.8 per cent, while at Cone 05 these were 2.4 and 8.8 per cent, respectively. This clay should not only make a good common brick, but there seems a possibility of using it for hollow brick and drain tile.

There is not much clay exposed along the road from Appomattox to Pamplin, but near the latter locality there are cuts of light gray material, of which some was tested.

The clay (Lab. No. 2064) is sandy and micaceous, and not of very high plasticity. It takes less water to mix it (26 per cent) than many of the other residuals, and has an air shrinkage of 6.5 per cent. The bricklets, while of good red color, should be burned to at least Cone 05 to give a good sound product. At Cone 010 the fire shrinkage and absorption were .3 and 21.2 per cent, respectively, while at Cone 05 these were 1 and 20.8 per cent, respectively. Although this clay could be used for common brick, it does not yield a hard product at as low a cone as some of the others.

One-half mile southeast of Pamplin in a new railroad cut, about half a mile long, and with a maximum depth of 25 feet, there is a large deposit of residual clay, whose structure points to gneiss as the parent rock. This

material (Lab. No. 2086) is red, and of very fair plasticity. The air shrinkage was 8.9 per cent, a little higher probably than it would be in actual practice. The average tensile strength was 88 pounds per square inch.

The clay fired to a good red color, and the bricklets had a fair ring even at Cone 010. The color darkened somewhat at Cone 03, and considerably at Cone 1.

On firing, the soft-mud bricklets gave the following additional data:

Cone	Fire shrinkage Per cent	Absorption Per cent
010	2.4	26.9
05	2.6	25.8
03	4.0	20.7
1	5.0	18.5

This clay should make a good common brick by the soft-mud process, and might possibly also work in a stiff-mud machine.

PITTSYLVANIA COUNTY.

Chatham.—Both the Triassic and pre-Cambrian gneiss and schist formations may serve as sources of residual clay around Chatham. Only the latter concerns us at this point. One deposit is exposed on a road, 1 mile northeast of Chatham Station. The clay is quite micaceous and was not sampled.

Another cut is about $2\frac{1}{4}$ miles north of east from the station. This section, which is about 300 feet long and 10 feet deep, shows no bedrock. The material (Lab. No. 2072) is a red-brown micaceous clay, of low plasticity. The air shrinkage is only 2.9 per cent, and the average tensile strength not over 15 pounds per square inch.

The clay burns to a red bricklet, but the product is not hard enough for service unless fired to Cone 03. At Cone 05 the fire shrinkage is 1 per cent, and absorption 25.5 per cent. At Cone 03 the fire shrinkage and absorption are 3.4 and 20.8 per cent, and at Cone 1 they are 3.6 and 22.3 per cent. The clay was tested in the stiff-mud machine, but would not flow through the die without tearing.

About half a mile farther east is another cut of residual clay from schist. And again, about 1 mile south by east from the station, is a brickyard that was operated up to about a year ago. The clay is light reddish-brown, and may be of colluvial character.

A sample of this material (Lab. No. 2067) was taken for testing. It is quite different from the other sample tested from Chatham. It worked up with 28 per cent of water to a mass of good plasticity, and had an air shrinkage of 5 per cent. The average tensile strength was 80 pounds per square inch. The bricklets burned red, and if fired to Cone 03 had a good ring.

The fire shrinkage and absorption at different cones are given below:

Cone	Fire shrinkage Per cent	Absorption Per cent
010	3.0	18.7
05	3.0	17.3
03	3.0	14.7
1	3.0	14.1

A sample was also tested in the stiff-mud machine, and flowed through both the brick and hollow-brick die without any trouble.

This clay could be used for manufacture of common brick and also for hollow brick. If worked in a stiff-mud machine it should first be put through a rolls to crush the scattered stones which it contains.

Danville.—The development of good brick and tile clays around Danville is of importance, partly because of local demand, and partly because it is a central point for several lines of railroad. The transported clays of this district have been referred to in an earlier page, but there still remain to be mentioned the residual clays of the pre-Cambrian gneisses and schists. These clays are widely distributed in the Danville area, and may vary considerably, according to the rock from which they are derived.

Two samples were tested, which serve to indicate the more important differences in the clays that occur in the vicinity of Danville.

Several openings have been made at Danville to obtain clay for the manufacture of brick. One of these supplies at the present time the yard of Watson and Fitzgerald. The material is derived from schist, and, at the point where worked, the thoroughly weathered rock or clay does not exceed 4 or 5 feet in depth.

The clay (Lab. No. 2029) has good plasticity, an air shrinkage of 8.3 per cent, and an average tensile strength of 87 pounds per square inch. It burned red, and had a good ring at Cone 010. If fired at Cone 03 the shrinkage shows a noticeable increase, and the color darkens perceptibly. The bricklets burned steel hard at Cone 03.



(A) Drying racks, Danville.



(B) Brick kilns, Deacon, east of Lynchburg.

Other tests were as below :

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	1.7	29.8
05	1.7	26.9
03	7.3	12.5
1	7.7	12.8

The clay makes a good common brick, and works in a stiff-mud machine as well as a soft-mud one.

Not far from Watson and Fitzgerald's yard there is obtained a whitish clay, derived from a weathered pegmatite, which is used for making boiler-setting brick.

About 6 miles west of Danville, near the trestle of the Danville and Western Railroad over Dan River, there is a shallow cut of residual clay, which is quite different from that at Danville. As the cut is shallow, the exact extent of the deposit could not be determined without boring. The material (Lab. No. 2063), although gritty to the feel, is of good plasticity. It has 6.4 per cent air shrinkage, and 94 pounds per square inch tensile strength. It burns red, and has a fair ring even at Cone 010, but does not become steel hard until Cone 03.

On firing the soft-mud bricklets they were found to have a low fire shrinkage, and moderate absorption as can be seen from the tests which follow :

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	0.0	25.5
05	1.0	19.6
03	3.0	16.3
1	3.0	15.4

This is a good brick clay, and is better than the material being used at Danville at the present time.

HALIFAX COUNTY.

South Boston.—No brickyards are in operation at South Boston, although one was formerly operated near the depot. The ferruginous clays derived from schist are to be seen at a number of points, but the cuts are all too shallow to afford good samples. There seems a strong probability, however, that brick clays can be found in the vicinity of South Boston.

GRAYSON COUNTY.

Galax.—Although only transported clays are worked around Galax, residual clays are not lacking. For example, three-quarters of a mile east of Galax, on the road to Hillsville, there is a cut of red, yellow, and brown clays, which are fairly typical of the residual rock materials found in this vicinity. Indeed, there is probably considerable clay at the point where the sample was taken. The material (Lab. No. 2115) has good plasticity, burns to a red color, and at Cone 010 gives a brick with a good ring.

The air shrinkage is 5.4 per cent, and the average tensile strength 73 pounds per square inch. Further details of the tests are given below :

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	0.0	21.0
05	2.0	17.1
03	3.7	12.4

This clay should make a good common brick with the soft-mud process, and, while it was not tried in the stiff-mud machine, we believe it would work.

SUMMARY OF TESTS OF PRE-CAMBRIAN SCHISTS AND GNEISS CLAYS.

Laboratory No.	LOCALITY	Water required for mixing	Plasticity	Air shrinkage	Tensile strength, lbs. per sq. in.	Cone 010		Cone 05		Cone 03		Cone 1	
						Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption
		Per Cent		Per Cent		Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
2034	Louisa	33.0	.....	4.4	.....	0.0	23.7	0.4	20.0	.....	.....	.....	.....
2082	Louisa	24.0	.....	6.2	.....	0.0	19.1	.....	18.8	.....	.....	.....	.....
2087	Louisa	40.0	Fair	7.4	97.0	0.0	24.4	1.0	22.6	4.0	16.0	4.4	16.0
2081	Mineral	44.0	Good	9.5	122.0	1.3	28.1	1.3	26.6	7.6	12.2	8.0	12.4
2100	Mineral	.....	.....	7.8	72.0	0.0	23.0	0.7	22.1	3.0	16.4	4.0	16.3
2079	Appomattox	30.0	.....	7.9	.....	0.3	27.1	0.2	25.0	.....	.....	.....	.....
2030	Pamplin	23.0	.....	5.8	.....	0.4	12.8	2.4	8.8	.....	.....	.....	.....
2064	Pamplin	26.0	.....	6.5	.....	0.3	21.2	1.0	20.8	.....	.....	.....	.....
2086	Pamplin	44.0	.....	8.9	88.0	2.4	26.9	2.6	25.8	4.0	20.7	5.0	18.5
					Not over								
2072	Chatham	36.0	Slight	2.9	15.0	0.0	.....	1.0	25.5	3.4	20.8	3.6	22.3
2067	Chatham	28.0	Good	5.0	81.0	0.3	18.7	3.0	17.3	3.0	14.7	3.0	14.1
2029	Danville	43.0	Good	8.3	88.0	1.7	29.8	1.7	26.9	7.3	12.5	7.7	12.8
2063	Danville	27.0	High	6.4	94.0	0.0	25.5	1.0	19.6	3.0	16.3	3.0	15.4
2115	Galax	31.0	Good	5.4	74.0	0.0	21.0	2.0	17.1	3.7	12.4	.....	.....

COMMENTS ON THE TABLE.

From the tabulated tests above, the clays derived from the weathering of pre-Cambrian gneiss and schist show a variable amount of water required, and are usually of good plasticity. Their air shrinkage is quite variable, but the fire shrinkage is generally low. The absorption at both Cone 010 and Cone 05 rarely falls below 20 per cent, but not a few of the clays make a sound brick.

KAOLINS.

The term kaolin is properly applied to deposits of white-burning residual clay. These may be derived from the weathering of pegmatite, talcose schists, feldspathic quartzites, or granites free from iron-bearing silicates like biotite, hornblende, etc., or shales. In the Piedmont region of Virginia, only kaolin derived from the weathering of pegmatite occurs to any extent.

In the formation of kaolin from pegmatites, the feldspar weathers more or less completely to a white clay, while the white mica and the quartz resist decomposition. The crude kaolin may therefore consist of a mixture of white clay, fragments of quartz and mica, and even grains or lumps of undecayed feldspar. The depth of weathering may range from 5 or 10 feet to over 100 feet.

Such a mass in its natural condition is of little value, although it is occasionally used for fire brick, and it is therefore customary to put the clay through a washing test in order to eliminate the grit.

The method commonly followed is to disintegrate the clay thoroughly in water, after which it is run through a series of troughs of very low pitch. In its passage through the troughs the gritty particles settle out, so that when the water reaches the farther end of the troughing it contains only clay in suspension, and it is conducted into large tanks where the clay settles out. The clear water is then drawn off, and the wet clay in the bottom drawn off into filter presses where more water is squeezed out. The cakes of clay are then removed from the filter press, dried, and shipped to the factories for use.

Washed kaolins are used for several different purposes. The fine, white grades are employed in paper manufacture, and in the manufacture of white china or porcelain. For the last-named purpose they must burn white. Those which do not show an absolutely white color on burning, but exhibit a faint creamy tinge, can be employed in making C. C. ware, electrical porcelain, and sanitary ware.



(A) Church constructed of brick made from local clay and erected before the Civil War.



(B) Kaolinized pegmatite in railroad cut near Motley.

The kaolins tested came from three localities, viz.: (1) Motley Station, Pittsylvania County; (2) northwest of Altavista, Campbell County; and (3) near Roseland, Nelson County. The first two are derived from pegmatites or coarse-grained granites, the third from a syenite.

PITTSYLVANIA COUNTY.

Motley.—One mile south of Motley, in a cut on the Southern Railway, is a vein of kaolinized pegmatite, at least 50 feet in width, inclosed between walls of schist.

The material (Lab. No. 2186) in its crude condition is very coarse grained, containing numerous flakes of muscovite and angular fragments of quartz. It is therefore not available without some form of preparation.

A sample of it was put through the crusher, with the opening set at one-eighth of an inch, and then molded into bricklets. The crushed material was of low plasticity, and had an air shrinkage of zero. The bricklets were burned to Cone 9, and at this temperature showed 2 per cent fire shrinkage and 17.6 per cent absorption. They were also steel hard. The material might be worked in this condition to make boiler-setting brick.

Another sample was put through a washing test, and yielded 14 per cent of washed clay, which is a somewhat low return for commercial purposes. Some of the washed product was tested with the following results: Air shrinkage 4.6 per cent; color, after firing, cream-white. At Cone 1 fire shrinkage 1.7 per cent, absorption 41.5 per cent, clay not steel hard. At Cone 9 fire shrinkage 3.4 per cent, absorption 36.6 per cent, color cream-white, clay not quite steel hard.

Altavista.—On the Jackson property, $1\frac{3}{4}$ miles west of Hurt, there are several showings of kaolin, derived from pegmatite veins, cutting the pre-Cambrian rocks. The one vein visible in tunnel 300 feet south of river dips 45° N. 30° W., and is 30 to 50 feet wide. The Virginian Railway runs between Roanoke River and the tunnel, following close along the former, with the tunnel mouth about 65 feet above the track. Several small pits, dug presumably in the same vein, show much mica (muscovite), less than 1 inch in diameter. A tunnel was driven on strike of vein 45 feet, with a cross-cut halfway in, extending 32 feet from the tunnel, and exposing the footwall schist.

The material (Lab. No. 2187) is coarse-grained and contains an abundance of quartz and coarse muscovite. The material on the whole is not as coarse-grained as that described above south of Motley Station.

A sample was ground to pass through a ten-mesh sieve, and molded into bricklets. These had an air shrinkage of zero, and burned creamy white. They showed a moderate absorption, and became steel hard at Cone 9. The details of these tests are as below:

Cone	Fire shrinkage Per cent	Absorption Per cent
03	1.0	18.5
1	1.6	16.8
9	3.3	13.7

The material in its crude form could probably be used for common fire brick, if there is enough of it.

Another lot of the material (Lab. No. 2187A) was put through a washing test, and yielded about 15 per cent of washed product, which is not a high return for commercial purposes. This had an air shrinkage of 6.6 per cent, and burned to a faint cream-white color, but appreciably whiter than the material south of Motley. At Cone 1 the fire shrinkage was 2 per cent, absorption 32 per cent, and clay not steel hard. At Cone 9 the fire shrinkage was 3.4 per cent, absorption 24.1 per cent, and product steel hard.

NELSON COUNTY.

Roseland.—The syenite which carries the rutile in this district in places appears to be quite free of quartz, rutile, and other minerals; indeed, it seems to be practically pure feldspar. There are few natural outcrops, but about three-fourths of a mile north of Roseland, on the west side of the Roseland-Bryant highway, the remains of a kaolin plant can be seen.

No operations have been carried on here for 20 years, and the workings have caved in, so that an actual exposure of the kaolin is difficult to find. From the observations that could be made, the crude material appears to contain considerable quartz, but at the west end of the outcrop, or near the old workings, there seems to be very little quartz, which is very fine grained. The washed product (kaolin) is quite mealy to the feel, as though it contained considerable sericite.

Surrounding the kaolin is a ferruginous plastic clay, evidently derived from the gabbro, and containing lumps of weathered nelsonite. The kaolin washing plant is completely dismantled, but the product is said to have been sold for paper manufacture.

A test was run first on the crude kaolin (Lab. No. 2169) to determine its properties. The crude kaolin is white, fine-grained, and passes a 100-



(A) Steamshovel excavating flood plain clay at Deacon, east of Lynchburg.



(B) Tunnel in Jackson's kaolin deposit near Altavista.

mesh sieve. The plasticity developed on mixing the clay with 40 per cent water is only fair, and the air shrinkage, owing to the presence of a large amount of grit, is low, 2.9 per cent. It burns white, and even at Cone 1 is nearly steel hard, but as might be expected the absorption is high, and the fire shrinkage low. Thus at Cone 010 the fire shrinkage and absorption were 1.7 and 34.7 per cent, respectively. At Cone 05 the fire shrinkage and absorption were 1 and 33.7 per cent, respectively. At Cone 1 they were 4 and 29.1 per cent. At this last cone the bricklets had a good ring.

Two samples of the washed kaolin were tested, one in more detail than the other, and the results are tabulated below, for purposes of comparison.

	2167 From stock house	2168 From stock pile at old plant
Water required	40%	27%
Air shrinkage	6%	2%
Cone 010		
Fire shrinkage	.6%	2.0%
Absorption	35.1%	34.1%
Color	Faint cream white	Ivory white
Ring	Fair	Good
Cone 1		
Fire shrinkage	2.3%	4.7%
Absorption	22.3%	21.6%
Ring	Good	Good
Steel hard	Nearly	Yes
Cone 9		
Fire shrinkage .....	.....	5%
Absorption .....	.....	19.6%
Steel hard .....	.....	Yes

The two samples show some differences, but, as the plant is dismantled, it is impossible to state the exact cause. The burned bricklets when dry appear nearly white, but if wet they show a distinct ivory or very faint cream tint.

A sample of No. 2167 was made into a mixture consisting of kaolin, 10 parts; flint, 4 parts; Roseland spar, 8 parts; whiting, 2 per cent. This mixture was burned at Cone 9, and gave a body that was vitrified and white, with a scarcely noticeable creamy tint.

While the kaolin can not be recommended for use in the manufacture of the whitest china, there is no reason why it should not be employed

as an ingredient in the manufacture of floor tile, electrical porcelain, and sanitary ware.

Some material which, as nearly as could be determined, appeared to represent the tailings from the old washing plant was also tested (Lab. No. 2166). It is very white and sandy, but contains some reddish spots of the surrounding residual clay scattered through it. Its plasticity is naturally very low, and took only 27 per cent of water to mold it. The air shrinkage is also low, 1.1 per cent.

Only a few fire tests were made on it. These showed a very low fire shrinkage up to Cone 1. An absorption of 27.5 per cent at Cone 010, and of 22.6 per cent at Cone 1. At the latter cone it is nearly steel hard.

SUMMARY OF TESTS OF KAOLINS.

Laboratory No.	LOCALITY	Water required for mixing	Plasticity	Cone 010		Cone 05		Cone 03		Cone 1		Cone 9	
				Air shrinkage	Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage
		Per Cent		Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
2186	Motley, crude	0.0	Low	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2186-A	Motley, washed	4.6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2187	N. W. Altavista	20.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2187-A	Same, washed	6.6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2169	Roseland, crude	2.9	Fair	1.7	34.7	1.0	33.7	.....	.....	.....	.....	.....	.....
		1.1	Very	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2166	Roseland, tallings	27.0	Low	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
		2.1	Very	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2168	Roseland, washed	27.0	Low	2.0	34.5	.....	.....	.....	.....	.....	.....	.....	.....
2167	Roseland, washed	40.0	Low	6.0	35.1	.....	.....	.....	.....	.....	.....	.....	.....

as an ingredient in the manufacture of floor tile, electrical porcelain, and sanitary ware.

Some material which, as nearly as could be determined, appeared to represent the tailings from the old washing plant was also tested (Lab. No. 2166). It is very white and sandy, but contains some reddish spots of the surrounding residual clay scattered through it. Its plasticity is naturally very low, and took only 27 per cent of water to mold it. The air shrinkage is also low, 1.1 per cent.

Only a few fire tests were made on it. These showed a very low fire shrinkage up to Cone 1. An absorption of 27.5 per cent at Cone 010, and of 22.6 per cent at Cone 1. At the latter cone it is nearly steel hard.

SUMMARY OF TESTS OF KAOLINE.

Laboratory No.	LOCALITY	Water required for mixing	Plasticity	Cone 010		Cone 03		Cone 04		Cone 05		Cone 06		Cone 07		Cone 08		Cone 09	
				Air shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption
		Per Cent		Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
2186	Motley, crude	.....	Low	0.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2186-A	Motley, washed	.....	.....	4.6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2187	N. W. Atavista	20.0	.....	0.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2187-A	Same, washed	.....	.....	6.6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2189	Roseland, crude	40.0	Fair	2.9	1.7	34.7	1.0	33.7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2166	Roseland, tailings	27.0	Low	1.1	.....	.....	0.0	27.5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2168	Roseland, washed	27.0	Low	2.1	2.0	34.5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2167	Roseland, washed	40.0	Low	6.0	0.6	35.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

OTHER KAOLIN DEPOSITS.

Deposits of kaolin have been found at several other points in the Piedmont province, but none of them is being worked at the present time.

In 1904 a kaolin deposit was worked near Oak Level, Henry County. The kaolin is formed by the weathering of pegmatite dikes that cut the schists of the district. It was mined from circular pits, some of which were 80 feet deep. A washing plant was built and operated near the deposit.

The mica-bearing pegmatites around Ridgeway, Henry County, are frequently kaolinized to a depth of from 10 to 50 feet, but the material is not only too impure for white-ware manufacture, but is not found in sufficient quantity for working.

A kaolin prospect, 6 to 15 feet wide,^a is known to occur one and a quarter miles northeast of Forest, Bedford County. It is said to yield 27 per cent of washed material, which has an air shrinkage of 6.2 per cent, and at 1350°C a fire shrinkage of 16.4 per cent.

THE CLAYWORKING INDUSTRY OF THE VIRGINIA PIEDMONT PROVINCE AND ITS FUTURE.

The clays of the Virginia Piedmont province are at present developed to a comparatively small extent. Small brick yards are in operation at a number of points, and are run chiefly to supply a local demand, but around some of the large towns, like Lynchburg and Danville, several plants have been established. Future developments will probably be most successful, if started in the southern half of the Piedmont province, as the northern portion is easily supplied by the many yards of the Alexandria (Virginia) district.

The results of the tests given in the preceding pages show that there are many deposits of clay that can be successfully utilized for the manufacture of common brick by the soft-mud, or, in many cases, by the stiff-mud process. The sandy nature of many of the deposits precludes their being employed for the manufacture of dry-press brick. This same character requires that the clay should be well burned in order to get a product of the proper hardness, a fact that has been neglected by some.

Of the several classes of clays tested, the transported ones found along the rivers yield the strongest and the densest brick. Next to these come the

^a Watts, S. A., Mining and Treatment of Feldspar and Kaolin in the Southern Appalachian Region, Bull. 53, Bureau of Mines, 1914, 101 pages.

Triassic residual clays, one of which, from Wolftrap, Halifax County, is very plastic and dense burning. Some of the residual clays of the Cambrian formations, notably those near Gordonsville, Orange County, are very promising, and those derived from the volcanic rocks near Virso, Lunenburg County, yielded good results.

Of greatest areal extent are the residual clays from the granites and gneisses, and these often possess excellent plasticity. They burn to a good color and a moderately hard body, but the absorption is not as low as desired. The residual clays from the Catoclin schists (metamorphosed pre-Cambrian basalt) are less promising.

The tests also show that some of the residual clays can be applied to the making of hollow brick, and the same is true of the Triassic clays, especially those near Wolftrap, which in addition can be made into drain tile.

Attention should also be called to the kaolin deposits of Nelson County, which probably exist in some quantity. As pointed out, they can be utilized in the manufacture of certain grades of white ware.

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VIRGINIA GEOLOGICAL SURVEY
UNIVERSITY OF VIRGINIA

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DIRECTOR

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of the Virgilina District of
Virginia and North Carolina

BY

FRANCIS BAKER LANEY

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VIRGINIA GEOLOGICAL SURVEY
AND THE
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1917

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LETTER OF TRANSMITTAL

VIRGINIA GEOLOGICAL SURVEY,
UNIVERSITY OF VIRGINIA,
CHARLOTTESVILLE, December 15, 1917.

Governor Henry C. Stuart, Chairman, and Members of the State Geological Commission:

GENTLEMEN:—I have the honor to transmit to you herewith, and to recommend for publication as Bulletin No. XIV of the Virginia Geological Survey Series of Reports, a manuscript and illustrations of a report on "The Geology and Ore Deposits of the Virgilina District of Virginia and North Carolina," by Francis Baker Laney.

The Virgilina District, which lies partly in Virginia and partly in North Carolina, is one of the more important copper districts in the eastern United States that has produced considerable tonnages of ore. This report, prepared jointly by the Virginia Geological Survey and the North Carolina Geological and Economic Survey, embodies a detailed study of the ore deposits in parts of Halifax, Charlotte, and Mecklenburg counties, Virginia, and in Granville and Person counties, North Carolina, and should prove of considerable value in directing further attention to an economically important area of copper deposits. Since it supplies the needed detailed and accurate information on the ore deposits, it is confidently believed that it will stimulate further development and production of copper ores in the district.

Respectfully submitted,

THOMAS L. WATSON,
Director.

P R E F A C E

The publication of this report, entitled "The Geology and Ore Deposits of the Virgilina District of Virginia and North Carolina," is a new departure in State Geological Survey reports, since it represents a joint investigation of an important copper district lying partly in each state, carried on coöperatively by the Virginia Geological Survey and the North Carolina Geological and Economic Survey.

In order to insure uniformity for the district as a whole, the same geologist, Doctor Francis B. Laney, was employed by the Virginia and North Carolina Geological Surveys to make the survey in the two states under the general supervision of the State Geologists of Virginia and North Carolina. Doctor Laney was assisted in the field work in North Carolina for a part of the time by Doctor Joseph E. Pogue, of the North Carolina Geological and Economic Survey; and, in Virginia, by Mr. Joel H. Watkins, of the Virginia Geological Survey.

The investigation covers an area of approximately 550 square miles, including parts of Charlotte, Halifax, and Mecklenburg counties, Virginia, and parts of Granville and Person counties, North Carolina. Chapter I gives a short but concise geographic sketch of the district, including location, topography, drainage, soil, and climate, closing with a complete account of previous geologic work in the district in the form chiefly of an annotated bibliography. Chapters II and III discuss the general geology of the district and give a detailed description and classification of the rocks, their structure and metamorphism. Chapter IV comprises a detailed description of the veins and ores, in which the mineralogy of the ore and gangue minerals is fully described, and the relations of the copper-bearing sulphides to each other and the origin and deposition of the ores are discussed. Chapter V, entitled, "The Mines and Ores of the Virgilina District," gives a full description of the individual mines and prospects, closing with a discussion of the methods best adapted to the utilization of the ores.

The traverse map which has been used as the base of the geologic map accompanying this report was prepared in coöperation with the United States Geological Survey.

The author and the State Geologists wish to make grateful acknowledgment to all persons who have assisted in various ways in facilitating the work of this investigation.

THOMAS LEONARD WATSON,
State Geologist of Virginia.

JOSEPH HYDE PRATT,
State Geologist of North Carolina.

AUTHOR'S PREFACE

During the field work upon which this report on the Geology and Ore Deposits of the Virgilina District is based, the writer had the advantage of the supervision and advice of Messrs. Thomas L. Watson and Joseph Hyde Pratt, state geologists, respectively, of Virginia and North Carolina, and he wishes to gratefully acknowledge his indebtedness to each of these men who spared neither time nor expense in furtherance of the work.

To the U. S. Geological Survey and to the U. S. Bureau of Mines the writer is indebted for the privilege of carrying on in their laboratories the microscopical and mineralogical investigations necessary in the preparation of this report. Many of the facts regarding the texture and structure of the different minerals as well as the photomicrographs showing these structures would have been impossible without the use of the excellently equipped microscopical laboratory of the U. S. Bureau of Mines at Salt Lake City, Utah.

During part of the field work the writer had the assistance in North Carolina of Dr. J. E. Pogue, now Associate Professor of Geology in Northwestern University, and in Virginia of Mr. J. H. Watkins, now Geologist for the Southern Railway Company. Mr. Watkins also did the drafting necessary in preparing the geologic map and the plans and drawings illustrating the development work at the different mines and prospects. To these men the writer gratefully acknowledges his indebtedness.

To many of the operators and residents of the Virgilina district the writer is under many obligations. Among these are Mr. A. W. Tucker, former manager of the Seaboard mine; Mr. Robt. G. Lassiter, former manager of the Blue Wing mine; Dr. Franz Koempel, of the Littlejohn Copper Co.; the late Mr. Wm. M. Pannebaker, owner of much property in the district; Miss Florence Pannebaker; Mr. J. D. Battershill, formerly superintendent of the Holloway mine; Mr. H. C. Crowell, of the Virgilina Gold Mining Co.; Mr. F. Durgy, of the Durgy mine; and Mr. John Taylor. These persons spared neither time, pains, nor convenience in assisting the writer in his work in every way possible for them to do so. Without their interest and coöperation it would hardly have been possible to collect the data so necessary in the preparation of this report.

To Miss Florence Pannebaker the writer is greatly indebted for a collection of ores from the Cornfield Prospect No. 1, which enabled him to

determine the relationship between chalcopyrite, bornite, and chalcocite. This obligation is gratefully acknowledged in the body of the report, p. 87.

The people of the district without exception were greatly interested in the work and were always willing and glad to render any assistance within their power.

FRANCIS BAKER LANEY.

THE GEOLOGY AND ORE DEPOSITS OF THE VIRGILINA DISTRICT, VIRGINIA AND NORTH CAROLINA

BY FRANCIS B. LANEY.

GEOGRAPHY AND HISTORY.

GEOGRAPHICAL SKETCH.

Location.—The Virgilina mining district is crossed by the North Carolina-Virginia boundary line about 140 miles west of Norfolk, Va., and 40 miles east of Danville, Va. About one-half of the area, which up to the present has been the most productive, lies within each state. The North Carolina portion, as included in the accompanying map, comprises an area about 22 miles long and 18 miles wide, and lies in the northwest portion of Granville and the adjoining northeastern corner of Person counties. The Virginia area is longer but narrower, is about 50 miles long and 15 miles wide, and, excepting a narrow strip along the western side of Mecklenburg County, lies within Halifax and Charlotte counties. The town of Virgilina, from which it takes its name, and which is the principal railroad point, is a village of about 600 inhabitants, and is located on the State line near the center of the most productive portion of the district. The Norfolk and Danville division of the Southern Railway, on which the town is located, crosses the district, approximately following the state line, and renders the center of activity easily accessible. The northern end of the district, which contains a number of somewhat promising prospects, but no developed mines, is crossed by the Richmond and Danville division of the Southern Railway, which, after crossing the district between Keysville and Drakes Branch, two railroad and supply points in the north end of the area, turns southwestward and runs within the area near its western border to Dan River. The Durham division of the Norfolk and Western Railway crosses the Southern Railway at Denniston Junction, about 12 miles west of Virgilina, closely paralleling the western side of the district. Thus it is that no part of the district, except the extreme southern end, is without ample railroad outlet. The wagon roads for the most part are fair, and some of them are good.

Topography.—The Virgilina district lies wholly within the Piedmont Plateau, and presents the topographic features common to that physiographic province. The topography is mature, the hills are all well rounded, and relief is much subdued. In fact, there is little relief noticeable to the casual observer, except where streams have cut through the Virgilina ridge,

a low-lying, nearly flat-topped ridge with very gentle slopes, which forms the most prominent surface feature of the district. The most marked relief is along Dan River, which crosses the district near its center. This stream crosses the rocks approximately at right angles to the strike of the schistosity, and, where it cuts through the Virgilina ridge, the slopes are steep and the topography is rather rugged. The remainder of the district is without prominent relief, but is decidedly hilly.

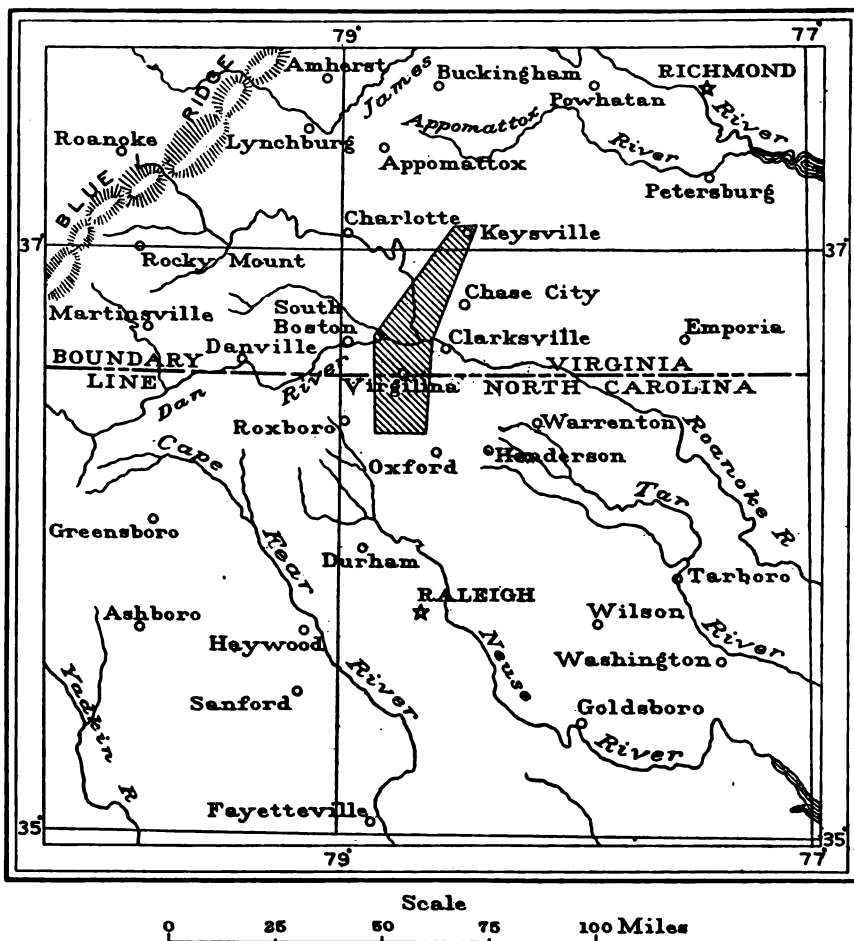


Fig. 1.—Map of a portion of North Carolina and Virginia, showing the location of the Virgilina district.

(Taken from a map of the United States by the General Land Office, 1915.)

Drainage.—The principal stream is Dan River, which flows in a south-east direction across the center of the district. Within the area the Dan is joined from the north by Bannister and Roanoke rivers, and from the south by Hyco River and Aaron's Creek. The Roanoke receives Horsepen Creek from the east, and Difficult Creek from the west, while Hyco receives Blue Wing and Mayo creeks from the east. These make up the principal streams, but rainfall during certain portions of the year is very heavy and smaller streams are numerous. The larger streams, especially Dan and Roanoke rivers, hold their course regardless of the character of the underlying rocks, but the creeks and smaller streams are greatly influenced, if not controlled, by it. Rainfall, especially during the winter and spring months, is heavy, and for the most part the district is well watered. >

Soil.—The character of the soil depends upon the nature of the underlying rock. The tuffs and other volcanics produce a lean, shallow soil; the granite produces a strong, rather sandy soil; and the other igneous rocks break down into a rather sticky but fairly strong soil. Of all the truly igneous rocks, the diabase produces the leanest and least desirable soil. The volcano-sedimentary rocks—the greenstone and sericite schists—as a rule form a lean and shallow soil. Rock outcroppings are not numerous except along stream courses, but almost invariably the partially decayed rock is very near the surface. Such soil is generally lean and does not produce good crops except when heavily fertilized. The granite is invariably deeply decayed, and produces the most fertile soils in the district. When properly cared for and well cultivated, the granite soils yield bountiful crops, and the most prosperous farms in the district are either in the rich, alluvial lands along the rivers or in the granite areas.

Much of the district is still in forest, but the greater part of the good timber has been cut off, so that what remains is either culled forest or "old field" pine. The original timber consisted largely of oak and other hardwoods with a moderate amount of yellow pine. The present timber, while for the most part second class and small, is ample for the needs in mining and for fuel.

Climate.—The climate of the Virgilina district is agreeable and pleasant throughout the year. As a rule it is neither excessively hot during the summer nor extremely cold during the winter. The mean annual temperature is between 55 and 60 degrees Fahrenheit. The winter temperature rarely reaches zero, and in summer does not often go above 90 degrees. Average yearly precipitation is between 50 and 55 inches and is fairly well

distributed throughout the year. There is only a moderate amount of snow, which comes during the months of January and February, and a single fall rarely lies on the ground more than a few days. It is therefore feasible to carry on out-of-door work throughout the whole year with little or no loss of time because of inclement weather. The heaviest rainfall comes during the early spring months and in the late fall. July and August are the driest and hottest months. Early autumn and late spring are delightful.

Culture.—All types and conditions of rural and village life common to the Piedmont Plateau are represented in the Virgilina district as included in the accompanying map, Plate I. The type of civilization and culture of the people of any portion of the district depends largely upon the fertility of the soil upon which they live. The rocks in which the ores are deposited produce a very lean shallow soil, and, as a consequence, the Virgilina ridge is thinly settled, and as a rule the farms are apparently not very prosperous. On the other hand, the alluvial bottoms and the granite soils are rich and fertile, and the farms located on these soils are well ordered and prosperous. Considerable intelligent effort is constantly being put forth to extend and improve the country roads, and its results are showing in graded, well-kept roads between all the principal towns and villages. More and more attention is being given to schools and to general social and economic development. The people are industrious, hospitable, and favorable toward outside interests that are calculated to in any way develop the district. In fact, many places in the district are as attractive and desirable for homes as any other places in this beautiful section of the United States.

The importance of the mining industry varies according to the market price of copper. As the mines are located, equipped, and operated it costs from 10c to 12c per pound to produce copper, and, as a consequence, when the price is low the mines are usually not operated. It is believed that by consolidating interests, or by working coöperatively, that the industry could be developed until it would at all times be a profitable business.

PREVIOUS GEOLOGIC WORK.

The first account of the region in which the Virgilina ore deposits occur is found in the writing of Col. William Byrd,^a who, as a member of a com-

^aHistory of the dividing line between Virginia and North Carolina, as run in 1728-1729 (published from the original manuscript), Richmond, 1866.

The Westover manuscripts. Containing the history of the dividing line between Virginia and North Carolina. Petersburg, 1841, pp. 1-102.

The writings of Colonel William Byrd of Westover in Virginia, Esq. (Edited by J. E. Bassett), New York, 1901, pp. 1-277.

mission appointed by the states of North Carolina and Virginia to settle a boundary line dispute, in 1728-1729, surveyed the boundary line between the two states from the coast to the Blue Ridge. A few names of streams commemorate the passage of the party through the Virgilina district. These are: Aaron's Creek, Blue Wing^a (spelled Blewing in Col. Byrd's manuscript, and so named by the party because of the presence of great numbers of a kind of water fowl called Blewings on the stream); Mayo Creek,^b named for William Mayo, a surveyor in the party; and Hyco River, to which Col. Byrd gave the name which had been applied to the stream by the Indians resident in the region, Hicootomony River,^c meaning Turkey Buzzard.

The account is one of the most readable of its kind ever written, and contains many valuable notes on the soil, the climate, the natural resources, and the general conditions of the country through which the party passed.

The earliest record of geological work in the territory, included within the accompanying map of the Virgilina district, is by Wm. B. Rogers^d in his report as State Geologist of Virginia for the year 1840. A part of Professor Rogers' work consisted of geological cross-sections at short intervals through the state from east to west. One of these sections (No. 95 in the plate of cross-sections accompanying the "Geology of the Virginias") was made on a line extending through Clarksville and Halifax Courthouse and passes through the central part of the district as mapped, while another similar cross-section made on a line from Belfield to Charlotte Courthouse passes through the northern part of the district. The chloritic and schistose character of the rocks were noted and remarked upon by him, and, as shown by notes in MacFarlane's Railway Guide, the geological data for which were supplied by Professor Rogers, it is clear that he regarded the rocks of the Virgilina district as of pre-Cambrian (Laurentian) age.

Of the section passing through Lunenburg, and Charlotte Courthouse, he remarks:^e

"The chief peculiarities presented in this line are the increasing abundance of the Hornblende slates and the Hornblende Gneiss, the occurrence of Chlorite, associated with numerous bands of quartz towards its western termination . . ."

^a Loc. cit., Vol. 1, p. 93.

^b Loc. cit., Vol. 1, p. 127.

^c Loc. cit., Vol. 1, p. 95.

^d Rogers, Wm. B.: Report of the progress of the Geological Survey of the State of Virginia for the year 1840.

Rogers, Wm. B.: A reprint of the annual reports and other papers on the geology of the Virginias. New York, 1884.

^e Geology of the Virginias, p. 481.

Further in the same connection, in regard to the section passing through Clarksville and Halifax Courthouse, he says that "the greenish chloritic and talcose rocks are largely expanded . . . "

Nothing was known at this time of the copper deposits in the district, unless the traditions in regard to the Barnes mine (see p. 144) are correct. It is reasonably certain, since Rogers does not mention the copper ores, that no mining or prospecting were in progress at the time of his field work in 1839.

The first published description of the ores of the Virginia district is a short account of the then recently opened Gillis mine, by Ebenezer Emmons, State Geologist of North Carolina, in his report on the Midland Counties,^a published in 1856. Emmons visited the district in the early spring of 1854, and studied the mine in considerable detail. He classified the country rock as "an altered slate belonging to the Taconic system." A brief description of the vein is given together with a list of both gangue and ore minerals. He remarks that the "vitreous copper" (chalcocite) did not change with depth to the "yellow sulphuret" (chalcopyrite) as was expected. The account closed with a statement that:

"The indications which the rocks furnish, taken in connection with the fact that there are other veins than the one described in this neighborhood, are that this part of Person and Granville (counties) will prove a mineral district of considerable importance."

In 1857 Dr. C. T. Jackson made a private report on the Gillis mine and the then known copper-bearing district from which Kerr and Hanna^b make the following quotation:

"The strata are occasionally disrupted by dikes; about half a mile, from the Gillis mine, and dipping westward to it, is a dike bearing N. 20 degrees E., containing abundant sprigs and grains of disseminated native copper. Epidote occurs both in the trap rock and in the quartz, and in the slate strata near the dike, which seems to indicate that the trappean rock is of the same geological age as the quartz veins."

The present writer visited this so-called dike and examined the intervening territory between it and the Gillis mine in close detail, and was unable to find even an indication of a dike. The rocks referred to as carrying native copper are portions of the massive andesite, and are usually, if not always, porphyritic and occasionally amygdaloidal. So far as our observations have extended, the only dikes at all closely associated with the

^a Emmons, Ebenezer: Geological report of the Midland Counties. North Carolina Geological Survey. Raleigh, 1856, pp. 344-346.

^b Kerr, W. C., and Hanna, Geo. B.: The ores of North Carolina: being Chapter II of the second volume of the geology of North Carolina, Raleigh, 1893, p. 219.

ore bodies are the diabase dikes described on pages 107 and 133, which bear no genetic relation whatsoever to the ores and veins. Such errors as the one just quoted were made before the nature of the rocks had been determined, and on such grounds are certainly pardonable.

In 1857 Emmons^a published his text-book of American geology in which he discussed in some detail his "Taconic" rocks of North Carolina, and the veins and economic minerals contained in them. He adds little or nothing to what was included in his report on the Midland Counties.

During the Civil War little or no mining was done in the Virgilina district, and, so far as the material available to the writer goes, little or nothing of importance was published on the geology between the appearance of Emmons' report on the Midland Counties, and the publication of Kerr's *Geology of North Carolina*^b in 1875. Accompanying this report is a geologic map of the state which places the Taconic rocks of Emmons in what Kerr called the Huronian, or the uppermost division of the Archean as defined by him, but nothing is said of the Virgilina district.

In 1893 there appeared Kerr and Hanna's^c description of the ores of North Carolina, in which is given a short description of the district as a whole, and detailed notes on the mines in operation when the report was written. These authors say that the formation immediately enclosing the veins is "chloritic slate," thus correcting the statement of Emmons^d that the rocks are argillaceous slates. This report gives a geologic map of the state on which the Virgilina district is located.

One of the most important papers bearing on the geology of a region similar in some respects to the Virgilina district, the Catoclin belt, was published in 1893 by Arthur Keith,^e who states that in 1890 he recognized the volcanic nature of the schists of Catoclin Mountain and the Blue Ridge. This was four years before Williams^f published his paper on the distribution of ancient volcanic rocks along the eastern border of North America, and two years before he published his article on the volcanic rocks in the

^a Emmons, Ebenezer: *American Geology*, containing a statement of the principles of the science, with full illustrations of the characteristic American fossils; 2 Pts. in 1 Vol., 1857.

^b Kerr, W. C.: *Report on the Geological Survey of North Carolina*, Vol. 1, Raleigh, 1875.

^c Kerr, W. C., and Hanna, Geo. B.: *The ores of North Carolina: being Chapter II of the second volume of the geology of North Carolina*, Raleigh 1893, pp. 214-221.

^d *Loc. cit.*, p. 345.

^e Keith, Arthur: *Geology of the Catoclin belt*, U. S. Geol. Survey, 14th Ann. Rept., Pt. I., 1893, p. 298.

^f Williams, George H.: *The distribution of ancient volcanic rocks along the eastern border of North America*, *Jour. of Geol.*, Vol. 2, 1894, pp. 1-31.

Catoctin region of Maryland and Virginia.^a It, therefore, appears to be clear that to Arthur Keith must be given the credit for first recognizing the true nature of the great group of volcanic rocks along the eastern coast of the United States.

Keith is also the first geologist who recognized in the Catoctin region of Virginia,^b and described in great detail, volcanic rocks similar in some respects to the volcanics of the Virgilina district. The sequence of the rocks in the Catoctin belt as determined by Keith^c is the same as in the Virgilina district. Other significant close resemblances between the rocks of the two localities are that they have approximately the same mineralogical and chemical composition (see pp. 33 and 34 for chemical analyses of the two), and the andesitic volcanics of both districts contain somewhat similar granite intrusives. These facts suggest that both are of the same age, and that both were deposited under somewhat the same conditions.

In 1894 Williams^d published his paper on the ancient volcanic rocks of the eastern border of North America, which served to call attention to the fact that such rocks exist in great quantity along the Atlantic seaboard from Nova Scotia to Alabama. He does not mention the volcanics of the Virgilina district, but discusses in considerable detail different types of volcanic rocks a short distance southwest of the district. This paper is one of the most important contributions to the geology of the general region in which the Virgilina mining district lies.

In 1896 there appeared a bulletin of the North Carolina Geological Survey by Nitze and Hanna^e on the gold ores of the state. They retain Kerr's classification of the metamorphic slates, as Huronian, but add considerable descriptive matter in regard to the rocks. Since the publication of Kerr's report some of the rocks making up his Huronian had been recognized as of volcanic origin. No detailed geologic work had been done in the Virgilina district and it is given about a page and a half, for the most part a brief summary of the data given in Kerr and Hanna's ores of North Carolina.

In 1899 Phillips^f published a popular account of the mining operations then in progress in the Virgilina district, adding very little to the knowl-

^a Am. Geologist. Vol. 8, 1892, p. 366.

^b Loc. cit., pp. 302-318.

^c Loc. cit., opposite p. 312 and p. 318.

^d Williams, George H.: The distribution of ancient volcanic rocks along the eastern border of North America, Jour. of Geol., Vol. 2, 1894, pp. 1-31.

^e Nitze, Henry B. C., and Hanna, George B.: Gold Deposits of North Carolina, N. C. Geol. Survey, Bulletin No. 3, Winston-Salem, 1896.

^f Phillips, William B.: Copper deposits of North Carolina, American Manufacturer, March 17, 1899; Abstract, Eng. and Min. Jour., Vol. 67, 1899, p. 382.

edge of the geology, beyond the conditions of mining and a partial list of the minerals making up the ores. He stated that the "country rock is slate, quartzite, etc., and porphyry belonging to the oldest formations, probably Laurentian, and in places impregnated with copper-bearing material apart from the seams (veins) themselves." He also published a similar account in *Mineral Industry*,^a describing in some detail the Holloway and Blue Wing mines.

In 1900 Weed^b published his "Types of copper deposits of the Southern United States," and in it gave the first detailed account of the geology of the district. Weed, so far as the writer is aware, was the first to recognize the true character of the rocks in which the deposits occur. He says, in this connection:^c

"The rocks are all of igneous origin—even the softest and most shaly show this character in thin sections under the microscope. But in a few instances only, is the igneous nature of the schists recognizable to the eye. This was observed at the Thomas mine, where a purplish rock is clearly a porphyritic meta-andesite. These schists are cut by dikes of later igneous rock (diabase). . . . Apart from the dikes, however, I would say, on the strength of field observations alone, that the rocks are of igneous origin, and belong to the various porphyries which have been discovered in the Appalachian belt. This conclusion is confirmed by microscopic examination of thin sections, which has shown the rocks to be altered andesites, that is, meta-andesites and andesite tuffs."

In addition to this interpretation of the rocks of the district Weed^d describes four types of copper deposits in the Southern United States as follows:

"1. The first type of deposit is that of a true fissure-vein, the quartz vein—formed by the filling of open cavities, with only minor and accessory replacement of country rock. The Virgilina deposits are representative of this type. The ore is glance and bornite, without chalcopyrite or pyrite. The veins cross the schists or conform with them.

"2. The second type is that of auriferous quartz veins common in the Appalachians. Although true fissure-veins, they are formed by the replacement of country rock along sheeting-planes or true fissures, and accompanied by the filling of open cavities as a minor and accessory feature. It is named from the Gold Hill mines, where such veins have yielded several millions in gold.

"3. The third type is a pyrrhotite-vein—a true fissure-vein the filling of which is essentially pyrrhotite or pyrite, almost barren of quartz, and represents the replacement of a zone of sheeted rock which was composed largely of metamorphic minerals.

^a *Mineral Industry*, Vol. 7, 1899, p. 211.

^b Weed, Walter H.: *Types of copper deposits in the Southern United States*, *Trans. Am. Inst. Min. Eng.*, Vol. 30, 1900, pp. 449-504.

^c *Loc. cit.*, p. 454.

^d *Loc. cit.*, p. 452.

"4. The fourth type comprises local segregations of native copper, copper oxides and carbonates along shear zones in altered igneous rocks. Such deposits, so far as known, do not extend below the groundwater level in depth."

The deposits of native copper in quartz and epidote, and in the greenstone schists without vein matter, are classified by Weed as belonging in his fourth or Catocin^a type. This paper also gives detailed descriptions of the veins and vein structure, and detailed accounts of the different mines then in operation (1900), together with methods and costs of operation.

In 1901 L. N. White,^b who at that time was superintendent of the Durgy mine, published a short paper setting forth his ideas of the geology of the district together with description of the veins and ores, with a short account of the development work.

In 1902 Watson^c published an important contribution to the geology of the Virgilina district. This paper deals in considerable detail with the general geology and in great detail with the petrography of the district, and is the first published description of these features. Watson clearly recognized the rock types most closely associated with the ore deposits as altered andesites and andesitic tuffs. The microscopic and chemical characters of the rocks are clearly set forth, but little attention is given to the ore deposits, so that the paper in a way supplements Weed's^d paper published two years before. The two papers taken together give a good and accurate account of the geology and ore deposits of the district.

Watson states his conclusions^e as follows:

"1. The rocks of the area here described have been greatly altered through pressure and chemical metamorphism, as indicated in the prevailing secondary schistose structure and the abundant development of the secondary minerals—chlorite, epidote, and hornblende—and small amounts of others. The alteration has advanced sufficiently far in the schistose phases to destroy in most cases the original structure and minerals of the rock.

"2. From structural, petrographic, and chemical evidences the rocks are shown to have been derived from an original andesite, but in their present much altered state they are, according to present usage, more properly designated meta-andesites; that these are intimately associated with the corresponding volcanic elastics. Furthermore, the popular name greenstone

^a Keith, Arthur: Geology of the Catocin belt, 14th Ann. Rept. U. S. Geol. Survey, Pt. 2, p. 309.

^b White, L. N.: The Virgilina copper district, Mining and Metallurgy, Vol. 24, 1901, pp. 635-639.

^c Watson, Thomas L.: Copper-bearing rocks of the Virgilina copper district, Virginia and North Carolina, Bull. Geol. Soc. Am., Vol. 13, 1902, pp. 353-376.

^d Weed, W. H.: Types of copper deposits in the Southern United States, Trans. Am. Inst. Min. Eng., Vol. 30, 1900, p. 453.

^e Loc. cit., p. 376.

applied to many areas of greatly altered massive and schistose rocks along the Atlantic Coast and Lake Superior regions, shown to have been derived from an original basic eruptive rock type, has equal application to the existing rocks of the Virgilina district.

"3. The rocks are pre-Cambrian in age and represent an area of ancient volcanics similar to others described as occurring along the Atlantic Coast region from Eastern Canada to Georgia and Alabama and in the Lake Superior region.

"4. The rocks are cut by numerous approximately parallel quartz veins which contain workable copper deposits. The veins have been described as true fissure veins, and the ore is glance and bornite without chalcopyrite and pyrite."

Early in 1906 Weed and Watson^a published a paper on the copper deposits of Virginia, several pages of which are devoted to the geology and ore deposits of the Virgilina district. It consists largely of restatements of data published by the authors in previous papers^b with notes concerning development work in the district up to the date of publication. They describe in some detail the rocks, veins, and ores, the greatest stress being laid upon the rocks of the area, which are correctly identified as andesites and andesitic tuffs. The following conclusions in regard to the rocks of the district are stated:

"1. The rocks have been greatly altered from pressure and chemical metamorphism, as indicated by the prevailing schistose structure, and the large development of secondary minerals, chlorite, epidote, and hornblende; and smaller amounts of others. The alteration has advanced sufficiently far in the more schistose phase to destroy, in most cases, the original structure and minerals of the rock.

"2. From structural, petrographic, and chemical evidence, it is shown that the rocks are derived from an original andesite. The altered andesite is intimately associated with the corresponding volcanic clastic. The name greenstone is applicable to the altered andesite of the district because of the abundant development of chlorite in it which imparts a somewhat distinctive green color.

"3. The rocks are pre-Cambrian in age and represent an area of ancient volcanics similar to others described from numerous localities along the Atlantic Coast region from eastern Canada to Georgia and Alabama."

Late in 1906, Watson^c published on the general geologic character and mode of occurrence of the copper ores in the Virginia areas, with notes on past production. The principal point of interest in this publication

^a Weed, W. H., and Watson, T. L.: The Virginia copper deposits, *Economic Geology*, Vol. 1, 1906, pp. 309-330.

^b Weed, W. H.: Types of copper deposits in the Southern United States, *Trans. Am. Inst. Min. Eng.*, Vol. 30, 1900, pp. 449-504.

Watson, T. L.: Copper-bearing rocks of Virgilina copper district, Virginia and North Carolina, *Bull., Geol. Soc. Am.*, Vol. 13, 1902, pp. 353-376.

^c Watson, Thomas L.: The Copper Deposits of Virginia, *Eng. and Min. Journ.*, Nov. 3, 1906, pp. 824-826. Map and figure.

is that the geology of the ores and associated rocks of the Keysville area in Charlotte County, which represents the northern extension of the Virgilina district, were described for the first time, and their identity with those of the Virgilina district farther south was pointed out.

In 1906 Judd^a published a short illustrated article on the Virgilina district, dealing in a popular way with the development of the district, and included short descriptions of the principal mines, and a few general notes on the geology of the district. Beyond bringing the account of the development of the district up to the date of publication, the article adds little to the geology that was not already known.

In 1907 Watson^b again published an account of the Virgilina district, summarizing what he had previously published in the different articles herein listed, together with additional notes on the development work.

In 1907, Weed^c included a brief summary of the geology of the copper deposits of the Virgilina district in his book entitled "The Copper Mines of the World".

In the early fall of 1908 the North Carolina Geological Survey published a preliminary outcrop and tentative geologic map of the North Carolina portion of the Virgilina district by Laney and Pogue.^d This is a traverse map on which the geology and veins and mines were shown. The work has since been revised and corrected, and the map and all the data shown on it are incorporated in the present report.

In 1910 the writer^e published a report on the geology and ore deposits of the Gold Hill district, a district lying about 150 miles southwest of the Virgilina district, which in part includes ore deposits and rocks similar in all respects to those of the Virgilina district. The two districts resemble each other in that their most important rocks are of volcano-sedimentary origin, which were first highly metamorphosed and rendered largely schistose, and then, later, intruded by large bodies of igneous rock, granite, diorite, and gabbro. Most of the volcano-sedimentary rocks of the Gold

^a Judd, Edward K.: The Virgilina copper belt, Eng. and Min. Jour., Vol. 82, 1906. pp. 1005-1008.

^b Watson, Thomas L.: Mineral resources of Virginia, Lynchburg, 1907, pp. 494-500.

^c Weed, Walter Harvey: The Copper Mines of the World, Hill Publishing Co., N. Y., 1907, 375 pp. Illustrated. (For Virgilina district in Virginia and North Carolina, see pp. 270-272.)

^d Laney, F. B., and Pogue, J. E., Jr.: An outcrop map of the Virgilina copper district, N. C., N. C. Geol. and Economic Survey, 1908.

^e Laney, F. B.: The Gold Hill Mining district of North Carolina, N. C. Geol. Survey, Bull. No. 21. Raleigh, 1910.

Hill district are rhyolitic or dacitic in character. There is, however, a fair-sized area of greenstone, massive and schistose, porphyritic and tuffaceous, and of basaltic or andesitic character which is very similar to the greenstone schists of the Virgilina district. It carries small deposits of copper ores similar in all respects to the Virgilina ore deposits.

Following the Gold Hill report there appeared in the same year (1910) a report of the Cid mining district of Davidson County, North Carolina, by Pogue.^a This district adjoins the Gold Hill district on the northeast, and contains similar volcano-sedimentary rocks, except the greenstone. The geology of the district is summarized as follows:

"Wide bands of a sedimentary, slate-like rock, composed of varying admixtures of volcanic ash and land waste, have the greatest areal extent. Intercalated with these occur strips and lenses of acid and basic volcanic rocks, represented by fine- and coarse-grained volcanic ejecta and old lava flows. The acid rocks include fine tuffs, coarse tuffs, and breccias, chiefly of a rhyolitic and dacitic character; together with flows of rhyolite and dacite. The basic series embraces fine tuffs, coarse tuffs, breccias, and flows of an andesitic and trachy-andesitic stamp. Gabbro and diabase dikes cut the other formations.

"The region has suffered a period of severe dynamic matamorphism or mashing, consequent upon a great compressive force which squeezed the beds into enormous folds; followed by a time of chemical alteration and mineralization; which in turn was succeeded by a long period of erosion and weathering. The rocks have suffered to a variable degree from all these factors. In general, each formation has a massive and a mashed or schistose phase, with every gradation between the two. . . . Finally, erosion has planed off all the upper portion of the folded series; but weathering has proceeded in excess of erosion to such an extent that the region is now deeply decayed, so that only here and there the rocks project through a thick mantle of decomposed rock or soil."

In 1911 the writer^b published an account of a detailed microscopic study of the ores of the Virgilina district with a few general statements in regard to the geology. In this paper it was shown by photomicrographs of polished sections of the ores that the chalcocite is of two periods of deposition, one later than the bornite and derived from it, and one intimately intergrown with and believed to have been deposited contemporaneously with the bornite, which was believed to be of only one period of deposition. The general conclusions as stated in the paper are as follows:

^a Pogue, Joseph E.: The Cid Mining district of Davidson County, North Carolina, N. C. Geol. Survey, Bull. No. 22. Raleigh, 1910.

^b Laney, F. B.: The relation of bornite and chalcocite in the copper ores of the Virgilina district of North Carolina and Virginia, Proc. U. S. Nat'l Museum, Vol. 40, 1911, pp. 413-424.

Laney, F. B.: The relation of bornite and chalcocite in the copper ores of the Virgilina district of North Carolina and Virginia, Economic Geology, Vol. 6, 1911, pp. 399-411.

"The rocks of the Virgilina district are greenstone and sericitic schists, which in places have been intruded by granite and gabbro. The intrusive rocks show none of the schistosity of the other rocks. The schists have been derived from a series of volcano-sedimentary rocks of two types—andesite and quartz porphyry, with a preponderating amount of tuffs corresponding to these rock types. Their age is probably early Paleozoic.

"The veins are true fissure veins which have a more northerly trend than the schistosity of the country rock, and the filling of which is quartz—about 70 per cent silica—with local and varying amounts of epidote and calcite. The ore-bearing veins are confined to the more basic portions of the greenstone schists, and the values lie in well-defined ore shoots.

"The ore minerals are bornite and chalcocite. They apparently prefer the quartz, but are not confined to any one of the gangue minerals. Bornite is present in slight excess over chalcocite, and is apparently of only one period of deposition. Chalcocite is clearly of two periods: One confined to the upper portions of the veins, more recent than, and filling a network of minute fractures in, the bornite; the other contemporaneous and intergrown often crystallographically with it. There is no evidence that any of the bornite is of secondary origin. It is, therefore, believed that in the Virgilina district the greater part of the chalcocite is a primary mineral contemporaneous with the bornite and in no way derived from it, or from any other copper-bearing mineral, by processes of secondary alteration."

In 1911, Weed^a published a rather detailed description of the geologic character and mode of occurrence of the ores and associated rocks of the Virgilina district in Virginia and North Carolina. Individual description was given of the principal mines, accompanied by many drawings as text-figures illustrating special features of the veins and ores.

DESCRIPTION OF THE ROCKS.

INTRODUCTION.

The Virgilina district lies wholly within the Piedmont Plateau and like that physiographic province is made up almost wholly of igneous and highly metamorphosed rocks. They include ancient metamorphic gneisses and schists the origin of which is unknown; a series of volcanic rocks of both acid and basic types and volcanic clastics of each type, together with much volcano-sedimentary material; intrusive rocks of both basic and acid types, such as gabbro, diorite, granite, and syenite; a small area of red or brown sandstone of Triassic-Newark age; and different types of dike rocks, especially diabase. Except the intrusives, the sandstone and the dikes, the rocks are all highly schistose and gneissoid in texture, the metamorphism having been so extensive in most cases that little of the original

^a Weed, Walter Harvey: Copper Deposits of the Appalachian States, Bull. 455, U. S. Geol. Survey, 1911, 166 pp., 5 plates and 22 text-figures. (For the Virgilina district, see pp. 67-89.)

structure and texture and few of the original minerals of the rocks remain. The acid volcanics originally were rhyolite or quartz porphyry and rhyolitic tuffs, but in their present condition are largely sericitic schists which may or may not show more than remnants of their original minerals and texture. In this report these rocks are described under the name Hyco quartz porphyry. The basic volcanics, for which the name Virgilina greenstone is proposed, were originally andesite and andesitic tuffs, but have become through intense metamorphism chlorite-epidote schists or simply greenstone schists. These for the most part retain something of their original minerals. The greenstone schists are more closely associated with the ore deposits than any other rocks in the district. In fact, so far as exploration has extended, the productive veins in the district are confined to these rocks. The rocks referred to as of volcano-sedimentary origin consisted originally of andesitic ash and tuff with which varying amounts of land waste were intermixed at the time of deposition, which probably took place under water. It appears that conditions were extremely variable at the time of their deposition, and that during some periods volcanic material predominated, and at others terrigenous material was most abundant. Thus some beds or bands of the rock consist almost wholly of volcanic material, while others are made up largely of land waste, while in much of it the two are about evenly mixed. Thus, on the one hand, these rocks may be fairly pure greenstone, and, on the other, fairly pure sandstone and conglomerate together with many beds made up of the two types of material in varying proportion. Like the other volcanics these rocks, which were called "sandy tuffs" during the field work, have been highly metamorphosed and are now gray, and greenish-gray, sandy schists with more or less of their original texture and minerals remaining. Some narrow bands are fairly pure conglomerate, some are largely argillaceous sandstone, others are fairly pure greenstone, but the greater part of the formation is made up of different amounts of each. The name Aaron slate has been proposed for these rocks.

The intrusive rocks, while they are deeply weathered and broken by joints, and have suffered more or less chemical metamorphism, are massive; that is, they show little or no schistosity. Of the intrusives, the gabbro, while it shows little or no schistosity, has suffered the greatest amount of alteration, which has been chemical rather than dynamic, and has to a great extent destroyed the original minerals of the rock.

The red and brown Triassic sandstones and conglomerates are much jointed and weathered. These rocks contain much shaly material, and

consequently are easily affected by the agencies of weathering. Aside from these alterations they are fresh and show no effects of metamorphism. This sandstone occupies only a small portion of the area—merely a patch along the west central portion of the district near the town of Scottsburg, and is of little importance so far as the general geology of the district is concerned.

The dikes, almost wholly of diabase, and of Triassic age, are widely distributed throughout the district, are always small, and are of little importance in the geology of the district. They are all deeply weathered, and, as a rule, have no surface outcrops except small rounded boulders scattered here and there on the surface along the trend of the dike. In the Blue Wing and also in the Durgy mine a dike was encountered in the development work. In the Blue Wing mine the dike intersects the vein. In neither case has the dike had any influence upon the ore, and their occurrence together in the two instances is wholly accidental.

The rocks will now be considered in greater detail, beginning with the oldest formations represented in the district, the biotite and the hornblende gneisses and schists. It might be well to state here that this report has to do primarily with the economic features of the district—the ore deposits—and that the writer believes it not best to burden it with too much detailed petrographic description. In this chapter, as in the report as a whole, he will endeavor to give only the most important features of the rocks and such details as appear to be necessary to a thorough understanding of the economic features of the district. While a detailed study of the rocks from a petrographic standpoint is, from the viewpoint of pure science, very desirable, the writer believes it would detract from rather than add to the usefulness and interest of a purely economic report. The practical mining engineer, the investor, and the mining public in general are much more interested in the facts closely related to the ore deposits and such considerations as their distribution, their relation to the rocks in which they occur, their continuation in depth, their mineralogy, and other practical factors, than in petrographic details. The rocks making up the ore-bearing horizon, the veins, the ores, and the structure so far as it may be of importance in studying, developing, and locating ore deposits, are therefore discussed in considerable detail, while many other factors of equal scientific interest are treated only in a general way.

GNEISSOID ROCKS.**Mica Gneiss.**

The oldest geological formation in the Virgilina district is a mica gneiss or mica schist, a narrow strip of which is included along the western side of the district as shown on the accompanying geologic map, Plate I. This formation has a wide distribution west, southwest, and northwest of the district, and, in fact, is one of the most important geological formations of the Piedmont Plateau. In general characteristics it closely resembles the Carolina gneiss of Keith,^a a formation of wide distribution in central and western North Carolina and South Carolina.

The rock consists of fine to coarse mica gneiss, mica schist, and fine granitoid layers. In places it contains veins and lenses of pegmatitic material varying in width from less than an inch to more than a foot. These usually lie parallel with the schistosity, but in some instances cross it. Quartz veins of similar distribution are not uncommon. It is indeed believed to be the same rock described by Keith and others as Carolina gneiss. In fact Keith's description of the Carolina gneiss of the Washington, D. C., folio is so characteristic of the mica gneiss of the Virgilina district that it might have been written with the Virgilina rock in mind. He says:^b

"The formation is composed of alternating layers of gneiss and schist of a prevailing gray color, dark bluish gray where fresh and greenish or yellowish gray where weathered. Individual bands vary from a few inches up to several feet in thickness, with an average of perhaps less than a foot. Both kinds of layers are highly siliceous, and are composed mainly of quartz, orthoclase, and plagioclase feldspar, muscovite and biotite. In places the rock contains numerous small crystals of garnet. Quartz and mica predominate in the mica-schist, and quartz and feldspar in the mica-gneiss, some of the latter having the aspect of a fine granite. Certain layers of the gneiss are to be seen in which the quartz and feldspar bodies have the appearance of sedimentary pebbles, a resemblance which is probably deceptive. These individuals are usually round; occasionally, however, they are flattened into "eyes." They seldom have a diameter greater than one-fourth of an inch. The original nature of the gneiss, whether igneous or sedimentary, is quite unknown. The thickness of the formation can not be determined in any way because there are no distinctive beds, but judging from the large area which the formation covers, its thickness is doubtless many thousands of feet."

The rock is deeply weathered; in fact, no natural outcrops were found except along stream courses. Typical exposures of this rock as well as of the hornblende gneiss may be seen along the Southern Railway near

^a U. S. Geol. Survey, Geologic Atlas of the United States, No. 70 Washington folio, 1901.

^b Loc. cit., p. 2.

Denniston Junction. The soils produced from this rock are usually light, somewhat clayey, and red or reddish-brown in color.

Hornblende Gneiss.

Occurring in intimate association with the mica gneiss are narrow and irregular areas and dike-like bands of hornblende gneiss. This rock tallies very closely in texture, composition, and in mode of occurrence with the Roan gneiss of Keith.* In fact his descriptions of the Roan gneiss, so far as texture and composition go, are equally applicable to the hornblende gneiss of the Virgilina district. The color is usually a greenish-black, but in some instances is considerably lightened by a greater amount of white material, for the most part plagioclase feldspar, but with varying quantities of quartz. It is a well-defined gneiss, consisting of alternating bands of hornblende and the light-colored minerals just mentioned. The texture of the rock varies considerably, but it is usually of medium grain. There is no way of determining its age or its original condition. It is believed, however, to be younger than the mica gneiss and intrusive into it. As compared with the mica gneiss it has a small distribution, and is not found in any other formation in the district. Like the mica gneiss it is deeply weathered, and natural outcrops are rare.

VOLCANO-SEDIMENTARY ROCKS.

INTRODUCTION.

The rocks designated as of volcano-sedimentary origin are by far the most important formations in the Virgilina district, and make up at least three-fourths of its areal extent. Under this group are placed both the acid and basic flows and tuffs, and the water-laid tuffs and slates. They occur as narrow belts or bands with fairly regular outline, and extend the whole length of the district. They, especially the basic (andesitic) flows and tuffs, are the most resistant rocks of the region, and form the most prominent elevations in the district, the Virgilina ridge, and also constitute the ore-bearing horizon. The geologic relation of these rocks to the underlying schists and gneisses is not definitely known. They are believed to rest unconformably upon the gneisses and schists, although it is possible that they were brought in by faulting. However, if such faulting exists, no

* U. S. Geol. Survey, Geologic Atlas of the United States, No. 90 Cranberry folio, 1903.

evidence of it was detected. For convenience of description the formations will be treated under the following formation names: the Hyco quartz porphyry, the Aaron slate, the Virgilina greenstone, and the Goshen schist.

The *Hyco quartz porphyry* consists largely of quartz-sericite schist, which represents a mashed and otherwise metamorphosed quartz porphyry or rhyolite, and which was tuffaceous in certain areas. The formation appears to be the oldest of the volcanic rocks, at least its areal distribution indicates that it underlies the other volcanics. It occurs as a narrow belt on each side of the district as shown on the accompanying map, Plate I. Its largest and most typical exposures occur along Hyco River, from which it is named.

The name *Aaron slate* has been applied to a slate-like rock formed by mixtures of varying amounts of andesitic volcanic ash and ordinary land waste, which through pressure and other agents of metamorphism have been changed or altered into a kind of hybrid slate—in some places into a schist. It varies from nearly pure greenstone to fairly pure argillaceous sandstone and slate, and in certain places is decidedly conglomeratic. It is realized that the rock is by no means a normal slate, and the term slate was applied to it only after much hesitation and many vain attempts to find a better name. It is the formation immediately overlying the Hyco quartz porphyry, and, like it, is exposed in long narrow bands on each side of the district. It is well exposed in many places along Aaron's Creek, from which the name is taken.

The name *Virgilina greenstone* has been given to the schistose greenstone in which all the developed ore deposits are located and which forms the Virgilina ridge. It is the altered equivalent of andesitic flows and tuffs and, while always more or less schistose, is, in some places, decidedly porphyritic and in others plainly tuffaceous. It occurs as long and narrow bands which make up the backbone, as it were, of the district. The rock occurs in typical development in and near the town of Virgilina, whence the name.

The term *Goshen schist* is applied to a highly schistose acid tuff, probably a tuffaceous phase of the Hyco quartz porphyry. In most places it is so highly altered that little or nothing of its original structure and texture is discernible. Its manner of occurrence and its relations to the adjacent formations strongly suggest that it is the same as the Hyco quartz porphyry, only much more tuffaceous. It is so named because of its typical occurrence in the southeastern part of the district in the vicinity of Goshen.

Hycø Quartz Porphyry.

Occurrence.—The Hycø quartz porphyry or rhyolite lies unconformably above the mica gneiss and the hornblende gneiss, and occurs as a narrow band on each side of the Virgilina district as shown on the accompanying geologic map, Plate I. In a few localities the rhyolite is apparently lacking. In two places, one in the extreme southwest corner of the district, and the other a short distance southwest of the confluence of Dan and Roanoke rivers, the formation is cut out for a short distance by the Redoak granite. It is also apparently missing for a short distance along the western side of the district near the town of Clover. In the extreme southeast portion of the area the place of the rhyolite is apparently taken by the Goshen schist, which probably represents the highly metamorphosed tuffaceous phase of the quartz porphyry.

The largest area of the formation is found on the west side of the district along Hycø River. At this place it attains its greatest width as well as its most typical development. In some places there occur quartz veins apparently similar to those in the Virgilina greenstone, but almost invariably without ore, or, if not wholly barren, carrying only a trace of valuable metal.

Macroscopic description.—It must be borne in mind that, while this rock is described as a quartz porphyry or rhyolite, the name applies more appropriately to its original than to its present condition. If one regarded only the present texture of the rock, he would call it a sericitic schist, which in fact the rock really is. Since much of the formation retains enough of its original texture and minerals to enable one to recognize it as a quartz porphyry, it was decided to describe it under that name.

While the Hycø quartz porphyry is, in all instances, decidedly schistose, there is usually, except in the decidedly tuffaceous phases, and in some cases even in these, enough of the original texture of the rock remaining to enable one to identify it with the unaided eye with a considerable degree of accuracy. It occurs in two phases, one of medium texture and decidedly porphyritic, with phenocrysts of both quartz and feldspar, and the other plainly tuffaceous or fragmental. While much of the rock is tuffaceous and so highly metamorphosed that its original texture has been more or less completely destroyed, the greater part is to a considerable degree massive and is clearly porphyritic. The strike of the schistosity as well as its dip is similar to that of the other schistose rocks of the district, and varies from N. 10 degrees to N. 40 degrees east. The dip so far as was observed is always toward the southeast from 70 to 80 degrees.

The color of the rock is usually light gray, that of the porphyritic phase always so, while the tuffaceous phase varies from light gray to purplish-gray, the color being due to iron oxides. About all that can be learned with the unaided eye in regard to the rock's texture and mineralogical composition is that it is usually highly schistose, has a dense light gray or nearly white matrix in which are numerous phenocrysts, mashed out into lens shapes, of feldspar and quartz. Sericite, recognizable because of its pearly luster, coats the surfaces of the fragments of the more highly schistose phases. In the tuffaceous phases the fragments are mashed and smeared out, but are easily recognized, especially when a cleavage surface of the rock is examined. On such a surface the fragments show as irregular blotches or spots of varying color.

Few, indeed almost no, natural outcrops of this formation were seen. The rock seldom outcrops at all except in and along streams, and in road and other artificial cuttings.

Microscopic description.—In thin section, under the microscope the following minerals are recognizable: Quartz, orthoclase, plagioclase varying from albite to oligoclase-andesine, hematite, and sericite in large amount. The phenocrysts are frequently fragmental, and the quartz usually shows resorption embayments. These are irregularly distributed throughout a dense, usually cryptocrystalline groundmass of quartz and feldspar in individuals so small that the microscope all but fails—in some instances does fail—to resolve it. The alteration products of the rock usually contain much sericite, which is readily distinguishable by its high polarization colors. The feldspar phenocrysts are all much altered, but they are usually fresh enough for identification. Quartz phenocrysts were not found in all specimens of even the most massive phases of the rock. When they occur at all, they are usually in anhedral forms, occasionally as well-defined crystals, and rarely as fragments, and show well-formed resorption embayments filled with groundmass material. The feldspars, both orthoclase and plagioclase, occur in short, stocky prisms. They often show twinning and in rare instances zonal development. They are often fragmental and in most instances so badly altered that identification is by no means an easy matter. Sericite is always present in large amount and at times is the most prominent mineral in the rock. All phenocrysts show the effects of mashing in that they are more or less in the form of lenses or “eyes,” and they usually show typical undulatory extinction.

A few minor accessory minerals, such as zircon, apatite, hematite, etc., are present, but in such small amount that they are unimportant.

Chemical composition.—A specimen of the typical porphyritic quartz porphyry was selected for chemical analysis and gave the results in I in the following table. Numbers II to V, inclusive, are analyses of somewhat similar rocks from localities to the north of the Virgilina district in Pennsylvania and Maryland and to the southwest in Davidson County, North Carolina, and are included for comparison. It is clear from the analyses that the rocks are all closely related, the principal differences being in the lime and alkali content and minor variations in the amount of silica. Analysis V is of a sericite schist from South Mountain, Pennsylvania, and is almost a duplicate of the analysis of the Virgilina quartz porphyry. Both rocks have suffered a high degree of metamorphism. It is believed that, during the alteration from a rhyolite to a sericite schist, the greater part of the Na_2O might be removed while the K_2O uniting with other elements to form sericite would remain. It is perfectly clear from the analyses that the rocks are all similar, and that if one is a quartz porphyry all are quartz porphyries.

Analyses of quartz porphyry.

	I	II	III	IV	V
SiO_2	77.78	74.67	73.62	76.34	73.45
Al_2O_3	12.78	10.78	12.22	11.60	13.77
Fe_2O_3	2.09	1.25	2.08	2.41	2.76
FeO	0.31	2.11	4.03	0.30	
MgO	0.77	Trace	0.26	0.06	1.22
CaO	0.24	1.47	0.34	0.55	None
Na_2O	0.54	5.31	3.57	5.50	0.18
K_2O	3.63	2.68	2.57	2.75	4.47
H_2O —	0.06	0.59	0.40	0.10	3.08
$\text{H}_2\text{O}+$	1.60			0.39	
TiO_2	0.28	.....	.....	0.26	0.21
P_2O_5	0.66	.....	.....	Trace	0.03
MnO	Trace	1.30	.....	Trace	.....
CO_2	Trace	.....	.....	Trace	.....
	100.74	100.16	99.09	100.26	99.17

- I. Typical quartz porphyry, Blue Wing Creek, 3 miles north of Christie, Va. Wm. M. Thornton, Jr., Analyst.
- II. Rhyolite from Flat Swamp Mountain, Davidson County, North Carolina. J. E. Pogue, Analyst, Bull. No. 22 N. C. Geological Survey, 1910, p. 54.
- III. Devitrified rhyolite from South Mountain, Pa. C. H. Henderson, Analyst, Williams, G. H., The volcanic rocks of South Mountain in Pennsylvania and Maryland. Am. Jour. Sci., Vol. 44, 1892, p. 493.
- IV. Aporhyolite, Monterey, Berks County, Pa. H. N. Stokes, Analyst, U. S. Geol. Survey, Bull. 150, p. 343, Florence Bascom.
- V. Sericite schist, Pine Grove Furnace, South Mountain, Pa. W. T. Schaller, Analyst, U. S. Geol. Survey, Bull. 419, p. 30.

Weathering and soil.—Except in localities, such as along stream courses, where erosion is exceptionally active the quartz porphyry weathers somewhat, but very little faster than the débris is removed by erosion. Hence, aside from such localities, and in road and other artificial cuttings, the rock is almost invariably covered with shallow soil. Along streams it forms rather rugged bluffs of dirty gray color. The soil is usually thin, lean, sandy, and not very productive unless heavily fertilized.

Goshen Schist.

General description.—The term Goshen schist is used to designate a highly schistose, clastic, acid rock, probably of volcanic origin which is extensively developed in the southeastern portion of the Virgilina district in the vicinity of Goshen. Microscopic examination of thin sections of the rock renders it reasonably certain that it is the metamorphosed equivalent of an acid tuff. It is, therefore, not at all improbable that it represents a very highly metamorphosed area of the tuffaceous phase of the Hyco quartz porphyry, and that it should be included with this formation. If such is the case, the most careful search failed to find any conclusive proof of it, and, until proof is found, it is thought best to keep the two formations separate.

In the hand specimen this rock presents a very fine-grained texture, has a light gray color, and is decidedly schistose. No phenocrysts are discernible, and the lack of noteworthy features, excepting the smeared-out fragments, is probably its most important characteristic. The fragments are best seen on a cleavage surface, upon which they are mashed out almost to a paper-thin condition, and each fragment has a slightly different color from the mass of the rock and the adjacent fragments.

In its present condition the Goshen schist is a well-defined sericite schist, and does not show even a vestige of the original texture or minerals of the rock. In this respect it differs very much from the Hyco quartz porphyry, which always presents something of its original characteristics. The microscope, while failing to reveal the texture and minerals of the original rock, does very clearly show that it was a rhyolitic tuff. It is light gray or almost white in color, very dense, and fine-grained except where the schistosity and secondary minerals have changed the texture, and is highly schistose. It weathers into a light-colored or ashy soil of no great degree of fertility, very much like the soil of the Hyco quartz porphyry. So far as is known no ore deposits of any kind occur in the rock, hence a detailed microscopic

and chemical examination was not made. The distribution of the formation is shown on the accompanying geologic map, Plate I.

Aaron Slate.

Occurrence.—The Aaron slate has an areal extent almost if not quite three times as great as any other member of the Virgilina series, and as regards distribution it is the most important formation in the district. It occurs as the other formations of the district in long narrow bands, the largest of which extend the whole length of the district, except where they are cut out by the Redoak granite. The rock is found in typical development on each side of the Virgilina greenstone which forms the Virgilina ridge. Its greatest development is in the southern portion of the district along a line from Mill Creek on the west side of the district to Adcock's store on the east. Its least development is in the northern portion of the area near Keysville. Between the Pannebaker prospects southwest of Virgilina and the Pontiac mine, a narrow lens of Aaron slate occurs in the Virgilina greenstone, while to the south is a single point and to the north from this included area are two points or tongues of the slate extending into the greenstone. Also about one mile east of St. Matthew's Church a narrow lens of the slate is enclosed in the Goshen tuff. Its distribution is shown on the accompanying geologic map (Pl. I), to which the reader is referred for details.

Macroscopic description.—Much hesitancy was felt by the writer in calling this formation a slate, and indeed during all the field work it was designated as "sandy tuff," but it is believed that the name slate is more suitable than the term sandy tuff. According to strict usage the formation is neither a tuff nor a slate, but a kind of compromise between the two. While there is much variation in texture and composition, the formation in the main appears to be made up of varying proportions of volcanic debris—ash and small fragments of an andesitic nature—and land waste, which varied from mud through fairly pure quartz sand to small pebbles. That is, the formation was originally built up of such material.

Like the other members of the Virgilina series of volcanic rocks it has suffered intense dynamic and chemical metamorphism, and, in its present condition it is for the most part a more or less sandy chloritic slate, varying, however, from nearly pure sandstone and conglomerate to nearly pure greenstone similar in all respects to and not distinguishable from the Virgilina greenstone. The purest sandstone found in the formation is



(A) Outcrop of Aaron slate, showing alternating bands of nearly pure sandstone and slate. The dip is toward the southeast. Railroad cut three-fourths mile west of Virgilina.



(B) Typical outcrop of Virgilina greenstone (tuffaceous phase). A short distance west of wagon road, two miles southwest of Virgilina.

exposed in a cut west of the town of Virgilina. At this place the beds of nearly pure sandstone are separated from each other by thin partings of slate. The dip and strike of the beds are shown better at this place than at any other known locality in the district. This exposure is shown in Plate II (A).

The conglomeratic beds are well shown at many places along Blue Wing and Aaron creeks. The most typical conglomerate, and also that containing the largest pebbles, occurs in a small cut on the Southern Railway about one-fourth of a mile west of the trestle over Blue Wing Creek. The conglomeratic beds, which are badly mashed and highly schistose at this place, can be easily traced for considerable distances both northeast and southwest of the railroad. In this bed pebbles 3 inches in diameter are common, and some 6 inches in diameter are occasionally found. The matrix is apparently fine sand with only a minimum amount of volcanic material. Farther northeast along Blue Wing Creek many narrow conglomeratic beds consisting of small rounded quartz pebbles in a sandy chloritic matrix are exposed. East of Virgilina about three-fourths of a mile the conglomeratic beds are again exposed in the public road just east of Wolfpen Branch. The quartz pebbles are small, rarely an inch in diameter in these beds, and the matrix is the usual sandy, chloritic material. This conglomeratic horizon, believed to be the same as that along Blue Wing Creek and to have been brought to the surface again by folding and erosion, can easily be traced for some distance along the strike of the beds in both directions from the exposure in the wagon road.

In the hand specimen, with the unaided eye, one may readily distinguish the true character of this rock. The metamorphism has not been intense enough to destroy the sand grains, and they can always be recognized in the argillaceous and chloritic matrix. The color of the rock depends upon its composition. When it is made up largely of quartz sand, the color is gray, and with increase of argillaceous and chloritic material becomes darker and greener. In natural outcrops the color is usually a dirty, greenish-gray, almost the same as that of the lichens which cover its surface.

Microscopic description.—The microscope reveals little of importance in regard to this rock that was not evident in a careful examination with the unaided eye. Quartz, chlorite, epidote, zoisite, black ores, especially hematite, sericite, calcite, occasionally a grain of feldspar, and much fine clay-like material make up about all the minerals revealed by the microscope. The minerals present in any section as well as the proportions in which

they occur always depend upon the nature of the rock. If it contains much volcanic débris it will approach the Virgilina greenstone in mineralogical composition, and will contain much chlorite and more or less green hornblende, much epidote and zoisite, with a small amount of quartz and varying amounts of calcite. If, on the other hand, it approaches a sandstone in composition, it will present a great deal of quartz, varying amounts of clayey material, and a minimum amount of chlorite, hornblende, and other minerals characteristic of the greenstone. If the specimen is taken from an area that has suffered intense metamorphism, the quartz grains will almost invariably show granulation around their borders, hornblende will be more prominent, and much of the original texture, and many of the original minerals will have been destroyed through recrystallization. Schistosity is well shown by the parallel arrangement of the minerals, as well as by the "Augen" structure of the larger quartz grains and pebbles.

Chemical analysis.—Very little of value is to be learned from a chemical analysis of a rock of such variable nature as the Aaron slate. The chemical composition will vary as widely as the physical. However, a specimen of what was considered typical material was selected for chemical analysis and gave the following results:

Analysis of typical Aaron slate.

(Wm. M. Thornton, Jr., Analyst.)

SiO ₂	70.53
Al ₂ O ₃	13.21
Fe ₂ O ₃	3.46
FeO	1.93
MgO	1.06
CaO	2.38
Na ₂ O	4.56
K ₂ O	0.40
H ₂ O+	0.05
H ₂ O—	1.06
TiO ₂	0.78
P ₂ O ₅	0.38
MnO	Trace
CO ₂	Trace
	99.80

The high percentage of silica is due to the quartz sand. The alumina and alkalis are probably for the most part from the clayey material, with smaller amount from the feldspar fragments which occur sparingly in the rock.

Weathering and soil.—Natural outcrops of the Aaron slate are inconspicuous and rare except along stream courses where it forms rather rugged bluffs. Throughout the greater part of its area the rock does not outcrop. The soil, however, is usually shallow and not very fertile. The character of rock decay and soil from the formation varies according to the nature of the rock in the particular area. The sandy beds produce a light, sandy, fairly fertile soil, while those which contain little sand and are made up largely of volcanic material, produce a thin, lean soil very much like that of the Virgilina greenstone. Between these two extremes there are all variations. The soil is, as a rule, not regarded as very desirable for agriculture, and much of it is not in cultivation.

Virgilina Greenstone.

Introductory statement.—The term Virgilina greenstone as used in this report includes the greenstone schists that form the country rock in which all the commercial ore deposits of the district thus far discovered are located. The formation in its present condition is a well-defined greenstone schist. Originally it consisted of andesitic flows, porphyritic in texture, and of andesitic tuffs which in amount greatly exceeded the porphyritic phase. In many places the rock has been so profoundly metamorphosed that it is very difficult, without the use of the microscope, to distinguish the tuffaceous from the flow rock. However, in most cases there is little or no difficulty in recognizing the two phases. The two types are in all places very intimately associated with each other, in fact, so intimately that it would be impossible to separate them in mapping. There has, therefore, been no attempt to separate them on the accompanying geologic map, Plate I. The ore deposits are apparently as closely associated with one type of the rock as with the other and there is on this account no very urgent call for their separation in mapping.

Distribution.—The Virgilina greenstone occupies the central portion of the district, making up, for the most part, the Virgilina ridge. Excepting a few miles in the vicinity of Redoak, Va., where the formation is cut out by the Redoak granite, the greenstone extends the whole length of the district, and, indeed, much farther both to the northeast and to the southwest of the limits of the accompanying geologic map, Plate I. In both the southern and the northern portion of the area mapped the formation consists of a single band, while in the central portion it includes one or more narrow bands of Aaron slate. In addition to this there are at least three

elongated, lens-shaped areas of the greenstone included in the slate. As shown on the map one of these is crossed by the wagon road about two miles west of Wilbourn's store. Another occurs at Ragland's mill, and the third extends as a narrow band from near Green Level schoolhouse to a short distance north of Smith's store on the wagon road about halfway between the town of Clover, Va., and Lack's ferry.

One or the other phases of the greenstone forms the country rock of all the known ore deposits of commercial value in the district, and it may be seen in typical development, either porphyritic, amygdaloidal, or tuffaceous in piles of waste rock at all the mines and prospects in the district. Because no workable ore deposits have been found in other formations, the Virgilina greenstone is regarded as preëminently the ore-bearing formation of the district. This matter is discussed in considerable detail in the chapter on the veins and ores, but it may not be out of place to state here that it is believed that the greenstone supplied only the conditions suitable for the deposition of the ores, and that it is in no way related to the original source of the ores.

The greenstone has its greatest development in the vicinity of Moffett, where it attains a width of about four miles. Another place in which it is prominently developed is about two miles south of the town of Virgilina, in the vicinity of the Pannebaker prospects, where the formation is over three miles in width. Its least development is immediately south of where it is cut out by the Redoak granite. At this place it is less than two miles in width.

Macroscopic description.—The three types of the Virgilina greenstone are usually distinguishable in the hand specimen without great difficulty. Two of them, a porphyritic and an amygdaloidal type, are effusive rocks and the other is a tuff derived from the same magma. Of these the tuff is by far the most abundant. The porphyritic phase is common, but the amygdaloidal is only occasionally found. Except when highly schistose, in which condition the amygdules, which are generally composed of material differing in color from the mass of the rock, are mashed and drawn out so as to very closely resemble the fragments of the tuff, one can easily distinguish the amygdaloidal phase from the others. Certain phases of the porphyritic type, especially the fine-grained rock, are very difficult to distinguish from certain kinds of the finer-textured tuff. This is exceedingly difficult when both rocks are highly schistose, and in some instances it is possible only with the microscope.



(A) Outcrop of Virgilina greenstone, North Fork of Aaron's Creek, five miles north of Virgilina.



(B) Typical outcrop of Virgilina greenstone three miles northwest of Virgilina.

The color of the porphyritic and the amygdaloidal rocks varies greatly, but is usually a kind of grayish-green, the intensity of the color depending upon the relative amounts of chlorite, epidote, and hornblende in the rock. Some areas have a purplish-gray color, but this is not nearly so pronounced as with the tuffaceous rock, which is occasionally of a decidedly purple color. Many specimens of the rock, when viewed on a cleavage surface, present a kind of pearly lustre or sheen, which is probably due to the development of sericite or some other micaceous mineral in the planes of schistosity. It is also not usually possible from the examination of such a surface to distinguish the porphyritic rock from certain phases of the mashed tuff. The determinative characteristics of the porphyritic rock consist of phenocrysts of plagioclase feldspar which can be seen to good advantage only when the rock is broken at right angles to the planes of schistosity. They are also more readily seen on a slightly weathered than on a fresh surface. This is also true to a certain extent of the amygdaloidal rock. Further than these feldspar phenocrysts, massive epidote in varying amount and in irregular patches, a little secondary quartz, occasionally a small amount of secondary calcite, one can distinguish with the unaided eye little or nothing as to the texture of the rock. As regards the amygdaloidal rock, one is able in like manner to distinguish the same minerals, and in addition the fillings composing the amygdules. Typical outcrops of Virgilina greenstone are shown in Plates II (B) and III.

Microscopic description.—The microscope reveals the presence of the following minerals: Plagioclase, hornblende, chlorite, epidote, zoisite, calcite, clinozoisite, apatite, the black ores, and quartz.

The plagioclase is all more or less altered and much of it so badly decomposed that a positive identification is not possible. However, some of the freshest phenocrysts were measured according to the Michel-Levy method and found to conform to oligoclase, oligoclase-andesine, and andesine. The phenocrysts often present a short, stocky, prismatic development and are nearly always more or less shattered and drawn out into "eyes" indicative, of course, of the intense dynamic metamorphism which the rocks of the region have suffered. The feldspars of the groundmass occur for the most part in slender, prismatic crystals, and are very much altered.

The amphibole appears to be wholly secondary. It has a beautiful light green or light bluish-green color, is not at all strongly pleochroic, usually occurs in slender, prismatic crystals which are in many instances curved

or bent, and in all other characteristics seems to correspond to actinolite. In the material studied not even a vestige of the original ferromagnesian minerals remained. It is impossible, therefore, to state what the original nature of the rock was, whether an augite or a hornblende andesite.

Epidote occurs in varying amounts in all the thin sections studied. In some instances it makes up the greater part of the rock, while in others it is only sparingly present. Usually, however, it is very abundant. It generally occurs in irregular grains of varying size, and rarely shows well-defined crystallographic development. Aside from a variation in color from the usual pistachio green to a decidedly yellowish-green, the mineral possesses only its usual and normal optical properties. In some instances, especially in the rocks immediately associated with the native copper deposits, the rock is largely replaced by a mixture of quartz and epidote. In such cases the quartz and epidote are most intimately intergrown with each other. The mineral is also intimately associated, in some instances with chlorite and invariably, except in the quartz-epidote intergrowths just mentioned, with zoisite and clinozoisite when the last-mentioned mineral is present.

Zoisite and clinozoisite are alteration products and are derived largely from the feldspars. Consequently their abundance in any specimen of the rock is to a great extent determined by the degree of alteration which it has suffered. The two minerals are very closely related to each other genetically, and while not always occurring together they very often do. They are also very closely related to epidote, and in many instances the three are found together. In fact, epidote and clinozoisite frequently occur with gradations, the one into the other, and in some instances the three are found together. In fact, epidote and clinozoisite frequently occur with gradation, one into the other, and in some instances the same grain is part epidote and part clinozoisite. The usual mode of occurrence is in the form of irregular grains, although a prismatic form is met with occasionally. The two minerals have only their usual and normal characteristics.

Chlorite is one of the most abundant minerals of the Virgilina greenstone. It was present in large quantity in every thin section examined, and in many it was second in abundance only to the feldspars. It is an alteration product derived from the original bisilicate minerals of the rock—in fact, it is exceptional to find even a vestige of the original amphibole or pyroxene, the whole having been replaced by chlorite. The mineral in ordinary light has its usual light green or pea green color, and is seen to be slightly pleochroic. In addition to filling the areas originally

occupied by the bisilicate minerals, which it has replaced, it also fills irregular spaces in the rock, and fractures in the other minerals, especially the feldspars. Between crossed nicols it is seen to be made up of radiating bunches or tufts which have aggregate polarization, somewhat like that of chalcedony. Aside from this the mineral possesses only its usual and normal characteristics. The fact that chlorite is so very abundant in all phases of the rock, and at the same time all other ferromagnesian minerals are so rare, certainly justifies the name, "chlorite-epidote schist," which has been given to this rock.

Calcite is present in considerable amount in all phases of the rock. It is in all cases a secondary mineral, probably derived for the most part from the decomposition of the original lime-bearing minerals of the rock. It occurs in irregular areas and patches, fills fractures and veinlets, and in many instances appears to be replacing the feldspars and other minerals of the rock. In some specimens from near the mineralized veins calcite as well as quartz is very abundant.

Quartz occurs in fine granular condition in the groundmass, in some instances closely associated with the feldspar microlites, fills minute fractures, and in some instances appears to be replacing other minerals in much the same manner as the calcite. Like the calcite it is much more abundant in the vicinity of the veins. It is regarded as a secondary mineral.

The black ores are present in varying amount in all phases of the rock, the most abundant one being hematite. Ilmenite and magnetite appear to be present in about equal amount. They have their usual and normal characteristics. In some places hematite is so abundant that it can easily be distinguished in the hand specimen by the unaided eye. In such cases it occurs as minute flakes in the planes of schistosity.

Other secondary minerals, such as kaolin and sericite, occur in considerable amount. They have their normal and usual characteristics. Sericite is present in varying amount in the ores as a gangue mineral. In such relations it has been described by Rogers,^a who concludes from its association with bornite and chalcocite that the latter is a secondary mineral and not contemporaneous in deposition with the bornite. It is probable that much if not all of the sericite, especially that occurring with the ores, is of hydrothermal origin. Kaolinite, on the other hand, may originate either by hydrothermal or ordinary weathering processes. It is more abundant in the greenstone than sericite.

^a Rogers, A. F.: Sericite, a low temperature hydrothermal mineral, *Economic Geology*, Vol. 11, 1916, pp. 118-151.

The amygdaloidal phase of the greenstone is similar to the porphyritic phase in all respects as regard minerals, alteration products, metamorphism, and texture in general. It differs in that the amygdules are composed to a certain extent of minerals foreign to the rock, such as quartz and zeolites, in addition to the usual epidote, chlorite, and calcite; and in the texture of the groundmass of the rock in the immediate vicinity of the amygdules. All the thin sections studied showed the microlites of plagioclase arranged with their longest direction tangent to the circumference of the amygdule, an arrangement common in amygdaloidal rocks.

Tuffaceous phase.—As regards mineralogical composition, alteration products, color, relation to the veins and ores, and general metamorphism, the tuffaceous greenstone is similar to the porphyritic rock. It differs in texture, the proportion in which the different minerals are present, and consequently in chemical composition. In texture the rock is clearly fragmental, the fragments differing considerably in composition and color, and greatly in size and shape. They are all sharply angular, and vary in size from less than a centimeter to more than two feet in longest direction. The fragments have been so much drawn out in the dynamic metamorphism which the rocks have suffered, that it is difficult to recognize them with the unaided eye except on a surface parallel with the schistosity. In thin section under the microscope they are easily recognized. In color the fragments vary from the usual green of the mass of the rock through reddish-brown to a kind of purple.

Chemical composition.—In the table (pp. 33-34) are given chemical analyses of carefully selected material as nearly typical of the average Virginia greenstone as could be collected. It represents both the porphyritic and the amygdaloidal phases of the rock. Numbers I and II are from material collected by the writer; the others are from Watson's papers on the rocks of the Virginia district.^a

Certain features of the greenstone are brought out very clearly by the chemical analyses, and it may be best to call attention to them. Numbers I, III, and IV represent specimens of the porphyritic greenstone taken from widely separated localities, and yet they show a marked uniformity of composition throughout. These analyses, taken together with the equally uniform mineralogical composition of the greenstone as shown by the microscope, prove that the magma from which the rocks now forming the

^a Watson, Thomas L.: The copper-bearing rocks of the Virginia copper district, Virginia and North Carolina, Bull. Geol. Soc. Am., Vol. 13, 1902, p. 364.

Virgilina greenstone was derived probably as uniform in composition as such material usually is.

Numbers II, V, VI, VII, and VIII represent tuffaceous and highly altered material, and are not nearly so uniform. They are all low in silica, and three of them—V, VI, and VII—are high in alumina, indicating that instead of being pure andesitic tuffs they represent material with which considerable clay was mixed at the time of their deposition. High lime and carbon dioxide contents in I and VII indicate the presence of considerable calcite in the rock.

Classification.—The mineralogical composition of the greenstone, when taken into consideration with the chemical analyses of the rock, indicate very clearly its andesitic character, and also as clearly show that it has suffered profound alteration. It will be noted that the analyses of the porphyritic rock show a moderate silica content for andesite. This, however, only indicates that the rock is an andesite of intermediate composition. Nothing remains of the original ferromagnesian minerals of the rock, and it is therefore not possible to state whether the original rock was a hornblende or an augite andesite.

Analyses of Virgilina greenstone.

	I	II	III	IV
SiO ₂	62.86	47.61	64.12	62.32
Al ₂ O ₃	15.98	15.55	16.32	15.79
Fe ₂ O ₃	2.44	7.33	6.72	3.57
FeO	2.61	1.76	1.38	4.61
MgO	3.36	4.91	0.33	2.53
CaO	4.54	8.60	3.49	3.65
Na ₂ O	4.52	4.00	6.22	4.51
K ₂ O	1.22	1.52	0.53	0.76
H ₂ O—	0.09	0.04	0.34	1.89
H ₂ O+	2.19	2.70		
TiO ₂	0.89	0.78	Trace	0.06
P ₂ O ₅	0.52	0.45	Not det.	Not det.
MnO	0.10	0.13	0.64	0.35
CO ₂	Trace	4.97	None	None
	101.32	100.35	100.09	100.04

- I. Virgilina greenstone, porphyritic phase, Thomas mine. Wm. M. Thornton, Jr., Analyst.
- II. Virgilina greenstone, tuffaceous phase, Durgy mine. Wm. M. Thornton, Jr., Analyst.
- III. Virgilina greenstone, dark purplish gray, porphyritic phase, Cornfield prospect. Thomas L. Watson, Analyst.
- IV. Virgilina greenstone (porphyritic phase), Overby prospect. Thomas L. Watson, Analyst.

Analyses of Virgilina greenstone—Continued.

	V	VI	VII	VIII
SiO ₂	51.34	48.20	46.45	49.51
Al ₂ O ₃	20.07	22.10	13.79	22.42
Fe ₂ O ₃	7.03	7.61	7.60	10.03
FeO	4.03	3.95	6.41	2.42
MgO	4.18	0.86	9.81	2.81
CaO	2.83	8.86	10.13	7.68
Na ₂ O	1.83	4.90	Not det.	Not det.
K ₂ O	5.53	1.16	Not det.	Not det.
H ₂ O—	2.90	2.31	2.66	3.41
H ₂ O+				
TiO ₂	0.38	0.24	Trace	0.57
P ₂ O ₅	Not det.	Not det.	Not det.	Not det.
MnO	0.38	0.35	Trace	0.42
CO ₂	None	None	2.27	0.90
	100.50	100.54	99.12	100.17

V. Virgilina greenstone, bright schistose tuffaceous phase, Blue Wing mine.
Thomas L. Watson, Analyst.

VI. Virgilina greenstone, bright schistose, tuffaceous phase, Fourth of July prospect. Thomas L. Watson, Analyst.

VII. Virgilina greenstone, bright schistose, tuffaceous phase, Anaconda mine.
Thomas L. Watson, Analyst.

VIII. Virgilina greenstone, partially decayed, tuffaceous phase, Anaconda mine.
Thomas L. Watson, Analyst.

Weathering.—Natural outcrops of the Virgilina greenstone are not plentiful, and are rarely found except in places in which erosion is very active. The rock, however, does not decay very much faster than erosion can carry away the débris, and in no place is the rock covered with more than a few feet of soil.

Watson* in his paper on the rocks of the Virgilina district gives a detailed discussion of the process of weathering from which the following quotation is made:

"The decayed rock is of a pronounced yellowish-brown color, readily crumbling under slight pressure. It effervesced very feebly in dilute acid, indicating hardly more than appreciable traces of carbonates. When further digested for some time in very dilute hydrochloric acid, the brown coloring matter was removed and the residue consisted of the usual green products composing the fresh rock. The percentage of residue composed of the green colored minerals was very large.

"As indicated by the analyses of the fresh and decayed rock, the change has been one of hydration—the assumption of water, accompanied by the peroxidation of the iron and the partial removal of the more soluble constituents, lime, magnesia, and alkalis."

* Watson, Thomas L.: The copper-bearing rocks of the Virgilina copper district, Virginia and North Carolina, Bull. Geol. Soc. Am., Vol. 13, 1902, p. 374.

INTRUSIVE ROCKS.**Redoak Granite.**

General description.—Four areas of granite occur within the Virgilina district as shown on the accompanying map (Pl. I): One in the vicinity of Buffalo Lithia Springs; one in the vicinity of Redoak post-office; one in the extreme southwest corner of the district; and one, only a small patch, about one mile west of Christie. Of these the area in the vicinity of Redoak is the largest and of the most importance. It has roughly the form of an ellipse the longest diameter of which is about 15 miles and the shortest approximately 7 miles. In this area the rock is so deeply weathered that no natural outcrops could be found, although they were searched for with the greatest care. On this account very little could be learned as to the character of the formation as a whole. So far as could be learned from the few specimens that could be obtained, the rock is a medium-grained, light gray, biotite granite, rather quartzose, and containing orthoclase and plagioclase feldspars in approximately the same amount. The area of the rock is well marked by the loamy sandy soil which it produces. This is the strongest and best soil in the district, and is the most prosperous portion of the region.

The area of granite in the vicinity of Buffalo Lithia Springs is similar to the Redoak area. It is a light gray, medium-grained, moderately quartzose, biotite granite in which the orthoclase and plagioclase feldspars are present in about equal proportion. Natural outcrops are very rare, and on this account little can be said in regard to the uniformity of the rock. Thin sections of the rock under the microscope show the following minerals named in the approximate order of their formation: Apatite, zircon, biotite, orthoclase, microcline, plagioclase, and quartz. The rock in places shows considerable alteration, and such secondary minerals as kaolin, muscovite, sericite, epidote, zoisite, and chlorite are occasionally met with. Small areas of a coarse porphyritic granite occur as intrusives in this area of the granite. These have been described under the term Buffalo granite. The weathering and decay of this area are similar in all respects to that of the Redoak area.

The granite area in the southwestern portion of the district is similar in all respects to the areas just described and on that account need not be discussed in this place in detail. The topography is somewhat more rugged

in this portion of the district than in the other granite areas, and because of this outcrops of the rock are more plentiful which make it possible to learn more as to the uniformity of the rock than in the other areas. So far as could be determined the granite in this area is fairly uniform in both texture and mineralogical composition.

The small area of granite northwest of Christie is not well exposed, and very little could be learned as to its texture and general characteristics. So far as could be determined from the material available, it is considerably finer in texture than the other areas of the rock which have just been described.

The size and location of the granite areas within the Virginia district are shown on the accompanying geological map (Pl. I). It should be stated, however, in this connection that the boundaries of the different areas are only approximately correct. The rock in all the areas is so deeply weathered and so deeply buried beneath its own decay that outcrops are not plentiful enough to enable one to determine boundaries very accurately. The granite produces a soil very characteristic and very different from that of any other formation in the district, and by using the soil as a guide it was possible to locate the boundaries of the different areas with a considerable degree of accuracy.

So far as is at present known, there are no ore deposits in any of the granite areas, and, so far as observations have extended, there are no indications that any such deposits exist in the rock. Notwithstanding this it is believed that the solutions which deposited the ores were directly associated with the intrusion of the granite masses. This matter is discussed in detail in the chapter on the origin of the ores and need not be repeated here.

Buffalo Granite.

General description.—The term Buffalo granite is used to designate small masses or areas of a coarse porphyritic granite with very large feldspar phenocrysts which occur in the Redoak granite in the vicinity of Buffalo Lithia Springs.

The rock is a light gray, coarse-grained, porphyritic granite which differs from the main granite masses very little except in texture. The same minerals are present in both rocks, and bear in general the same relations to each other. The rock is present only in small amount, and, so far as could be determined, is of no commercial importance.

Abbyville Gabbro.

General statement.—A considerable area of much altered gabbro occurs in the vicinity of Abbyville. No prominent outcrops of the rock could be found, and because of this it has not been possible to learn much in regard to the texture and general characteristics of the rock as a whole. Such outcrops as could be found consist of irregular rounded boulders of a dirty greenish-gray color, which in some instances were altered more or less completely into an impure soapstone. The boundary of the formation as shown on the accompanying geologic map (Pl. I) was determined by the distribution of such boulders and by the color of the soil, and consequently is only approximately correct. The character of the particular outcrop depends upon the degree of alteration, and on this account a detailed petrographic description of the rock would involve more space and time than the importance of the rock from an economic standpoint warrants.

Macroscopic description.—In the hand specimen the gabbro usually has a kind of dirty greenish-gray color which varies greatly, depending upon the degree of alteration which the rock has suffered; the fresher the rock, the darker the color. Usually the rock is coarse-grained, and the individual minerals can be recognized by the unaided eye with considerable ease. The principal mineral thus recognizable is a light green hornblende. In many cases this is the only mineral that can be identified in this manner, but in a few instances other minerals, especially feldspars, are recognizable. The rock is generally very tough except the most highly altered phases, but even the freshest of it is moderately soft so that when an edge is struck with a hammer it usually mashes down to a whitish mass instead of flaking off.

Microscopic description.—In thin section under the microscope the following minerals are recognizable: Pale green uralitic hornblende, badly altered plagioclase feldspar, zoisite, clinozoisite, epidote, kaolin, sericite, chlorite, calcite, quartz, and black iron ores. The feldspars are so much altered that positive identification is not possible. They show clear indications of broad twinning bands, and doubtless belong in the lower and middle portion of the plagioclase series. The fact that lime-rich secondary minerals, such as zoisite, clinozoisite, epidote, and calcite, have abundantly developed from and are replacing the feldspars, is strong evidence that they were originally rich in lime. This type of alteration, known as saussuritization, is characteristic only of the lime-rich plagioclases. The

other minerals have their usual and normal characteristics, and need not be described in detail at this place. The calcite and quartz are both secondary minerals.

It must be stated in connection with the description just given that while it is true for the sections studied, other thin sections made from portions of the rock in different stages of alteration will certainly show different mineralogical compositions and very different petrographic characteristics. In fact, one thin section examined by the writer contained traces of the original pyroxene of the unaltered rock. Thus it is certain that by diligent and prolonged search one could find specimens of the gabbro that will show practically every stage of alteration from the fairly fresh rock to the impure soapstone.

Unaltered gabbro.—As indicated on the accompanying geologic map (Pl. I) there are two areas of gabbro in the southern portion of the district. The rock in these areas differs materially from that in the Abbyville area, and, indeed, may be an entirely different type of rock. In fact, there is much evidence that indicates that such is the case, and that the rock is intermediate between gabbro and diabase. On this account much hesitancy was felt in using the same colors on the geologic map for the different areas. The question can not be settled without more extensive microscopic and chemical research than the importance of the rock would justify, certainly more than an economic report would call for.

This rock, as seen in the field, is fairly fresh and is of a black or very dark brown color—not decidedly unlike that of a diabase. It has from a fine to a medium granular texture. It is very tough and heavy, and in places appears to contain an excess of iron ores. When examined in thin section, the rock presents the following minerals: Hypersthene, augite, calcic plagioclase which varies from labradorite to anorthite, and large amounts of black ores. With these primary minerals there are such secondary ones as always develop from such combinations of primary minerals.

NORMAL SEDIMENTARY ROCKS.

Triassic (Newark) Sandstone.

General description.—One small area of reddish-brown sandstone of Triassic (Newark) age occurs within the district mapped. As shown on the accompanying geologic map (Pl. I), this formation occurs as an elliptical area about ten miles long and four miles wide, in the west-central portion of

the district, extending from a short distance southwest of Wolftrap to about two miles northeast of the town of Scottsburg. Natural exposures of the rock are very rare, in fact only two or three are known to occur, and the outlines of the formation as shown on the map are only approximately correct. The best-known exposure of the rock is in the railroad cut a short distance northeast of Scottsburg, in which place it is decidedly conglomeratic, the matrix being moderately fine reddish-brown sandstone in which are embedded pebbles and boulders up to over a foot in diameter. The color of the rock varies from chocolate-brown through reddish-brown to almost a brick-red. The exposures of the rock are so scarce that it was not possible to learn very much in regard to the characteristics of the formation as a whole.

This is one of the disconnected areas of the Triassic which are of common occurrence in the eastern portion of the Piedmont Plateau of North Carolina and Virginia. The formation, while of much interest from a purely geological standpoint, is in no way related to the ore deposits of the region, and, on this account, is of no great importance from the standpoint of the present report.

DIKE ROCKS.

General statement.—As in all other parts of the Piedmont Plateau, dikes are numerous in the Virgilina district, and while they are of little or no economic importance they form one of the district's interesting geological features. They are as a rule small, but widely distributed, no formation being free from them. In age they vary from early Paleozoic to late Triassic, the oldest being the syenite, granite, and gabbro, and the youngest the diabase of late Triassic age. Disregarding the probability that at least a part of the hornblende gneiss of pre-Cambrian age was intruded into the mica gneiss in the form of dikes, the dikes of the Virgilina district may be divided into the following groups or classes, named in the probable order of their respective ages: Granite, syenite, gabbro, and diabase. The largest, longest, and most persistent are the syenite dikes, the others coming in the following order: Granite, diabase, and gabbro. Of these the diabase dikes are the most numerous and granite the least so.

Granite.

General description.—Only one granite dike was found during the field work. It occurs a short distance east of the railroad at Randolph station, and extends northward a short distance east of the railroad to near Moss-

ingford. Its width, as well as it could be determined, varies from 100 to about 200 feet, and the rock is fairly uniform throughout the entire length. The rock appears to be a medium- to fine-grained, light gray to red granite. Its relation, if any exists, to the main granite area in the vicinity of Redoak could not be determined. In some places, especially near the State Farm at Saxe, it outcrops strongly, but in most places the outcrops are inconspicuous.

Syenite.

General description.—Two peculiar granitic dikes, which appear from examination in the hand specimen to be syenite, were found in the district. Both of them occur in the northern part of the district, and both have a linear length of several miles. The larger and longer of the two is well exposed in the town of Drakes Branch, where it has a width of about 150+ feet, and from which it may be traced northward some six or eight miles and southward for about twenty miles. So far as could be determined from meager outcrops, it maintains a fairly uniform width throughout its entire length. According to the observations of Mr. J. H. Watkins, who did the field work in that vicinity, this dike intersects the Redoak granite, and is therefore younger than that formation. Beyond a limited use for road metal the syenite is not known to have any commercial value. Thus far no ore deposits have been found associated with it in any way, and there appears to be no reason to expect that any such deposits will ever be found.

In the hand specimen the rock is seen to be rather coarsely crystalline and to be made up largely of feldspars, having only minor amounts of ferromagnesian minerals and quartz. In color, texture, and general appearance the syenite somewhat resembles a coarse-grained granite.

Gabbro.

General statement.—In the vicinity of the larger masses of gabbro a few small gabbro dikes were found. They are always small, and as far as is known do not extend long distances. In color, texture, and, in fact, in all particulars, the rock of the dikes is similar to that of the main Abbyville gabbro area already described. It is, therefore, unnecessary to repeat the description in this place.

Diabase.

General statement.—The most abundant and also the most widely distributed dike rock in the Virgilina district is diabase. It occurs in the

form of numerous narrow dikes, the width and trend of which are indicated by the presence of small boulders, locally called "nigger heads," scattered here and there on the surface. The rock has been weathered so deeply that, so far as observations have extended, the massive rock does not outcrop naturally in the district. The dikes are always narrow, and have never been known to extend over great linear distances. The diabase is the youngest rock in the district, and is found cutting all the other formations, even the Triassic sandstone. It also has the distinction of being the only dike rock that is in any way associated with the ores, but this association is wholly accidental, and there is no genetic relation between the diabase dikes and the ore deposits. The dikes are much younger than the ores, and, where the two are associated, as in the Blue Wing and the Durgy mines, the dikes cut the veins without producing any effects upon the ores or veins.

Macroscopic description.—The diabase is a massive, fine-grained rock of a black or bluish color when seen on a fresh fracture, but often a dark gray color on a weathered surface. The rock is usually so dense and the texture so fine that with the unaided eye one can distinguish little or nothing in regard to its mineralogical composition. It is very heavy and is exceedingly tough.

Microscopic description.—In thin section under the microscope the following minerals, named in the probable order of their formation, are revealed: Black ores, olivine, plagioclase feldspar in narrow, lath-shaped crystals, augite, and in some instances a small amount of green secondary hornblende. The texture is typically ophitic, and the feldspar laths have a decidedly random or haphazard arrangement. The rock is similar in all respects to the diabase of the Piedmont region. It has no genetic nor other important relation to the ore deposits, and, as it occurs in this district, is of no commercial value.

STRUCTURE AND METAMORPHISM.

GENERAL STATEMENT.

In other chapters the nature of the rocks and ores have been discussed, and their relationships to each other have been considered. The rocks although profoundly altered, both physically and chemically, since their original deposition, have been identified and classified, and their areal distribution has been determined and shown on the geological map (Pl. I) which accompanies this report. The ores have been studied in their relation

to the rocks and veins in which they occur, and the component minerals of the ores have been considered in their relation to each other. These studies have shown that certain profound changes have taken place in the rocks in the district since the original deposition, that many causes have been active in the production of the results, and that to a greater or less degree each cause has left its own particular imprint or effect upon the rocks or ores, each, of course, more or less obscured by the succeeding. The agents producing these changes have been physical (pressure) and chemical (solution) rearrangement, and redeposition of the respective constituents.

In the present chapter it is proposed to consider the effects of these various physical and chemical agencies as recorded in the rocks and ores, and to draw such conclusions as to the forces producing them as seem logical. Under the term structure will be considered largely the physical agencies, such as folding, mashing, shearing, jointing, faulting, and the intrusion of igneous rocks. Under metamorphism will be considered both the physical agent, pressure, and the various chemical changes that are shown by the rocks to have taken place. These are all scientific and theoretical considerations, but upon them rest the very practical considerations as to continuance of the ore with depth, the character and type of rocks in which the prospector may search for ore with the greatest possibility of finding it, the effect of fractures and faults upon the ore bodies, the causes for the segregation of the ores in certain places rather than in others, the origin of the ores, their parent rocks, and many other questions of prime importance to the mine owner and mine operator.

STRUCTURAL FEATURES.

FOLDING.

The mashed and highly schistose character of nearly all the rocks of the district is the most evident effect of the enormous compression to which the region has been subjected. The fact that the slaty cleavage of all the rocks dips almost invariably to the southeast is another almost, if not equal, evidence of the tremendous forces that have been in operation at various times in the long-past history of the district. This prominent schistosity is one of the last results effected by forces of compression, and is developed only after a region is thrown into a series of folds and these closely compressed. There are a number of possible interpretations of the structure, but the one which the writer deems to be most probable is that of a closely

compressed synclinerium, the folds of which have all been overturned so that the dip is almost entirely toward the southeast. The forces of deformation have been so intense that the bedding planes and other original features of the rocks have been almost entirely obliterated. It is therefore only in rare instances that one may observe in the field the actual crests and troughs of the folds, or even the bedding planes of the rocks. Thus it happens that the presence of folds must be determined by circumstantial or inferential evidence rather than upon direct observation. Two concurrent lines of evidence, such bedding planes as can be found, and the areal distribution of the different rock formations as shown on the geologic map (Pl. I), offer conclusive evidence of folding.

Bedding planes or lines of stratification are found in a few places in the district, and, while their dip is almost always uniform and toward the southeast, there are in a few places observable variations from this direction which indicate clearly the crests of pitching folds. These conditions may be seen in a cut on the branch railroad near the switch running from the road to the Holloway mine, and in another cut on the same road about one-half mile south of the Blue Wing mine; in an exposure in the wagon road a short distance south of Jones Ferry; and to a less extent in an exposure in the wagon road where it crosses Wolfpen Branch about one-half mile east of Virgilina. In many other places there are obscure indications of similar conditions. The structure has been so greatly obliterated by the development of secondary features, such as schistosity and by the heavy overburden of decayed rock and soil, that it was not possible to locate on the accompanying geologic map (Pl. I) the anticlines and synclines, and thus work out the structure. The bedding planes are for the most part parallel with the schistosity, and usually have the same degree of dip. These conditions may be seen in almost any prominent rock exposure in the Aaron slate. It is especially well shown in a cut on the Southern Railway about one mile west of Virgilina, where many thin beds of dense slaty material alternate with thicker beds of nearly pure sandstone. (See Pl. II (A).) It is also noted that where the bedding planes diverge from the general northeast-southwest strike of the district, the rocks are much more massive and show their original textures fairly well, and that where they are parallel with the schistosity the rocks are highly schistose and have suffered intense dynamic metamorphism. These facts indicate pretty clearly that there has been much close folding, and the variation in character of the rocks may be explained by the fact that dynamic metamorphism is always more intense on the limbs of folds than on their crests. The more

massive rocks therefore indicate the crests or troughs of folds, while those more highly schistose and altered indicate the limbs of the folds.

An equally strong, if not a stronger, indication of folding is the areal distribution of the different rock formations of the district. This is best seen on the geologic map (Pl. I) on which the different formations are shown in different colors. It will be noted that there are two general types or forms of rock distribution shown upon the map, one consisting of long narrow bands terminating for the most part in sharp points, and of blunt, more or less ellipsoidal, areas, the former indicating the volcano-sedimentary rocks and the latter those intruded into them.

Even a glance at the geologic map (Pl. I) will show that in a general way the narrow bands repeat themselves with great regularity. Any cross-section will show that if one assumes a northeast-southwest axis through the center of the district, there is a regular sequence of formations on each side of this axis. This is well shown in the section exposed across the district along the Southern Railway. The center or axis crosses the railroad about the middle of the band of Aaron slate a short distance west of Virgilina. Both east and west of this point the formations are repeated in regular sequence. It must be assumed that such rocks as these must have been deposited originally in approximately horizontal beds or strata, one above another. As they occur to-day these strata are turned almost on edge, and are repeated in more regular sequence such as one might expect would result from folding.

These lines of evidence seem to prove that the district has been thrown into closely compressed folds whose axes have an approximate trend of north 30° east. The exact nature and the details of this folding are very difficult, if not impossible, to determine. If one assumes one large regular syncline such as the distribution of the formations and their relation to each other would seem to warrant, it still remains to explain the conditions which could permit the building up of beds or strata of rock varying in thickness from one to more than three miles. While this conclusion at first glance appears to be justified, closer study reveals another which it is believed more logically follows from the observations, and also has the advantage of not requiring the assumption of strata of such enormous thickness. Therefore while fully realizing that other interpretations are possible and logical, the one outlined below is the most plausible to the writer.

The district represents a closely compressed synclinorium consisting of numerous anticlines and synclines only a few of which are at present

determinable, the major axis of which has a northeast-southwest trend and is located approximately in the center of the district. The folding has been close, and the compression so intense as to impose strong schistosity having a trend parallel with the main axis of the synclinorium and a steep southeast dip. What might be assumed from the distribution of the formations as their thickness is apparent and not real, there being a number of minor synclines and anticlines on each limb of the major syncline. The probability of this interpretation is strengthened by the occurrence of narrow, spindle-shaped areas of one formation in another, the explanation being that they are portions of overlying or underlying formations brought down or up in compressed pitching synclines or anticlines. Assuming this to be the case, there is no reason for assigning a thickness of more than one-half mile to any formation, which would not be excessive for tuffaceous rocks.

While the axes of the major folds have a northeast trend, the shape of the different clastic formations indicate very clearly a minor series or system of folds with axes almost at right angles to the major series. The effect of the second series was to form the first anticlines and synclines into a series of cross-folds or folds with axes at right angles to the major series, and thus throw the whole district into a series of pitching synclines and anticlines. Two such cross-folds and their resultant saddles are clearly indicated in the distribution of the formations as shown on the geologic map (Pl. I), one with an axis running about 20 degrees west of north, apexes somewhere near the High Hill schoolhouse, and the other occurs in the southern part of the area. Its axis would lie somewhere along a line drawn from St. Matthew's church to Bethel Hill. It was not possible during the field work to obtain any direct observations such as dip and strike of bedding planes to prove the presence of these cross-folds, but the distribution of the different formations at these points is so typically characteristic of pitching folds that it seems logical to assume that they exist. If this interpretation is correct, the crest of any of the major folds would be described by a wavy line with crests and troughs, and the two localities just described are cross-anticlines, while to either side of them are corresponding synclines.

Another feature of the folding is that, with very few exceptions, the bedding planes of the rocks dip steeply about 70 degrees toward the southeast, and have a strike parallel with the major axis of the folding. The exceptions to these conditions, as far as could be determined during the field work, are few and irregular, and are strongly indicative of pitching folds.

in which case they would mark the troughs and crests of the folds. It is believed that the only explanation of this almost universal southeast dip of the strata is to assume that during the time of folding there was considerable thrust from the southeast toward the northwest, and that the folds were all overturned toward the northwest.

SCHISTOSITY.

Probably the most evident structural phenomenon of the district is the very prominent slaty cleavage or schistosity of the rocks. This almost invariably has a north to northeast strike, and a dip of from 60 to 80 degrees toward the southeast. In many places it corresponds to the bedding planes of the rocks where such can be distinguished, but on the crests and in the troughs of folds the schistosity maintains its usual dip and strike regardless of the bedding planes. In studying the structure of the district one must, on this account, be very careful not to confuse the primary planes of stratification of the volcano-sedimentary rocks with the schistosity, which is in no way related to the bedding planes, but has been induced by compression. It is not intended to affirm that all the rocks of the district are uniformly and highly schistose, for such is not the case. The intrusive rocks, which are younger than the volcano-sediments, show little or no schistosity, and were therefore evidently intruded subsequent to the period of intense dynamic metamorphism. Furthermore, in many places, probably on the crests and in the troughs of folds, and also in certain areas in which the rocks are massive—probably normal andesites instead of andesitic tuffs—the schistosity is not so prominent as to obliterate the other features of the rock. In many places schistosity has destroyed all the original textures and features of the rocks, and is so prominent that they may be split into slabs almost thin enough for use as slates. This is especially well shown in a bold outcrop on the north bank of Ran Diver, a short distance below the mouth of Hyco River. At this place, known as the Harris slate quarry, an attempt has been made to quarry the material for use as roofing slate, but, so far as the work has extended, the rock has not been found to be suitable for such purposes.

Since it is known that the secondary phenomenon slaty cleavage or schistosity is developed by compression, and that it forms in a direction normal to the axis of application of the force producing it, one may safely conclude that the forces producing the schistosity in this district acted in a northwest-southeast direction.

The forces producing the folding and schistosity had ceased long before the formation of the veins and the deposition of the ores, and, of course, have had no effect upon either. The vein matter shows no schistosity.

JOINTING.

Joint planes are prominent in all formations, but are more prominent in the more massive rocks, and are very abundant where the volcano-sediments lie most nearly horizontal, and least abundant where schistosity is greatest. In strike the joints tend to group themselves in the northwest and northeast quadrants of the circle, with a smaller group having an approximate north-south strike, and very few approximating the east-west direction. In dip their planes cut the horizon at almost all angles, but it appears that by far the greatest number have a steep easterly or south-easterly dip. In the schistose formations the majority of the joints have a north to northwest strike, and an east to north dip. It is probable that the small number of joints in these formations with northeast strike may be accounted for on the basis that, because of the prominent schistosity with northeast strike, it was easier for the joint-producing forces to relieve themselves along the planes of cleavage already developed than to produce new fractures. Many of the joint-planes show slicken-sided surfaces, and it is not improbable that along many of them there has been more or less dislocation, but it is believed that in the great majority of cases they are merely fracture planes and not planes of dislocation or fault planes.

The joint planes have been of far greater importance in the geologic history of the district than one might at first thought suspect. They have formed the openings in which both dikes and veins occur, except where the latter follow the planes of schistosity, which is not usual, and are thus the controlling factor in the location, trend, and dip of dikes and veins. It is realized that some of the veins may have been developed in fault planes, but, so far as could be determined during the field work, there is little conclusive evidence that such is the case, and it, therefore, appears safest to assume that by far the greater portion of the veins has been developed in joint planes, opened in part by the linear force of the crystallization of the vein matter, and in part by replacement of the country rock.

A few words should be said in regard to the time of development of the joints. Little evidence on this question is available; but what there is indicates that the joints were formed in large part since the close folding of the district and the development of the schistosity. Joints are fractures in the rocks, and hence are formed in the zone of fracture, while folding

and the development of schistosity are flow phenomena, and are necessarily developed in the zone of flowage.

Furthermore, as shown in the mine workings, the trend of the most prominent system of joints in the district so nearly coincides with the strike of the schistosity that it is difficult to conceive of the two having been developed simultaneously and by the same force. It is not believed that all the jointing is necessarily contemporaneous. Indeed it is well known that the region has been subjected to more than one period of elevation and depression, and it thus seems logical to believe that a certain amount of fracturing would take place during each period of earth movement. As has been stated and discussed in detail in the chapter on the origin of the veins and ores, it is believed that they are connected genetically with the intrusion of the great masses of granite of the region, small areas of which occurring in the district are shown on the geologic map (Pl. I). It is well known that at one period in the geologic history of the Piedmont region enormous masses of granite were forced into the already existing rocks, and it is believed that while it is probable that not all the granite was intruded at one time, by far the greater part of it came in during a single more or less extended period of intrusion. Such great bodies of magma coming into the zone of fracture would necessarily produce more or less fracturing, some of which would be very deep. Hence it is believed that many of the deep fractures, which later were filled with vein water and became the ore deposits, were formed contemporaneously with the granite intrusions.

The system of fractures in which the veins occur appear to have been formed by a force applied so that the stress could be relieved in part by tearing the rock apart along the planes of schistosity, and in part by fracturing the rocks along planes forming very acute angles with the schistosity, thus giving the veins the appearance of fissures combined with "stringer lead" or rifted schist type of veins.

FAULTING.

There is but little direct or conclusive evidence of faulting in the district, and such as there is consists of minor displacements of a few feet in some of the ore bodies or veins. It seems hardly probable that so much dynamic metamorphism could have taken place in the district without producing a certain amount of faulting on a large scale. However, if such exists, it was not detected. It is not at all improbable that many of the prominent veins, both barren and ore-bearing, were developed in fault

planes; but, if they were, no direct evidence of it was detected, unless the thin laminæ of quartz and ore in the rifted schist which forms part of the vein in many places, or the slicken-sided walls which are found occasionally, are such evidence. The lenticular character of the veins, their pinches and swells, when explained on the theory of Becker that the fracture represented a wavy line and that any movement of either wall would tend to bring two crests and two troughs of the fracture opposite each other, and thus produce the pinches and swells, is also evidence of at least a small amount of displacement. While technically such movements along fracture planes is faulting, yet the results from a structural standpoint might be negligible, and, while it is possible that some of the veins were formed in planes of profound displacement, one certainly is not justified in assuming it from such evidence as that just stated. If such faults exist they were formed prior to the formation of the veins and the deposition of the ores, since these show no evidence of any such movements.

In three of the mines, the Seaboard, the Blue Wing, and the Durgy, there is minor faulting which affects the veins in a small way.

The dislocation in the Seaboard mine is at the south end of the 200-foot level, and the vein appears to be cut out completely by a cross-fault. There is little doubt as to the fault, but the development work has not been sufficient to furnish data as to the amount of displacement. Such evidence as could be obtained indicates that it is probably a minor fault, and that the displacement is slight.

The displacement or faulting, as exposed in the Blue Wing mine, occurs on the level immediately north of the diabase dike. The vein is shattered and displaced a few feet. The fault is probably contemporaneous with the intrusion of the dike.

The dislocations reported in the Durgy veins are all trivial, and appear to be similar to that in the other veins. They have no important influence upon the ore body and the dislocation is slight. Indeed it may not be faulting at all, and may be similar to a mud-filled fracture which Weed^a states was encountered north of the shaft on the third level of the Holloway mine, which, while shattering the walls, did not displace the veins.

It is believed that these minor fractures and faults were probably developed during the earth movements attendant upon the outpouring of the basalt and diabase, and the intrusion of the trap dikes along the Atlantic Coast during Triassic times. So far as could be determined, they

^a Weed, W. H.: Copper Deposits in the Southern United States, Trans. Am. Inst. Min. Eng., Vol. 30, 1900, p. 460.

have had no influence upon the vein development, nor upon the mineralization and enrichment of the ore deposits.

INTRUSION OF IGNEOUS ROCKS.

Intrusive rocks occur in considerable quantity in the district. They range in character from diabase and gabbro to syenite and granite. They all have been discussed in more or less detail in the chapter dealing with the rocks, and descriptions need not be repeated here. The syenite, diabase and much of the gabbro, and smaller amounts of the granite and diorite occur as dikes. The intrusion of these masses of magma has had little effect upon the structure of the district, in fact much less than might be expected. About the only effects so far as noted, aside from the probability that the granitic intrusions are responsible for the solutions which formed the veins and ores, and the opening up of joint planes by the dikes and more or less bending of the planes of schistosity in the schists by the bodies of igneous rock.

METAMORPHISM.

General statement.—The term metamorphism is intended to be used broadly enough to include all changes which have taken place in the rocks of the district since their original deposition or intrusion. There are no means of learning even approximately all the changes that have taken place in the rocks of the district, nor of knowing the agencies which produced them, but enough of the previous, if not original, textures of the rocks remain to enable one to trace some of the changes that have taken place. Changes are produced by two kinds of agencies, each producing its own results, though modified, of course, by the other. These agencies are physical, represented by compression, and chemical, represented by metasomatism, solution, and deposition or precipitation.

TEXTURAL CHANGES.

The effects of dynamic metamorphism as shown by folding, jointing, faulting, and schistosity have all been discussed in considerable detail in another place in this chapter. All types of rocks of the district, except the Triassic sandstone and diabase dikes, which have been formed since the period of dynamic metamorphism, show more or less clearly a record of the changes that have taken place. Through pressure combined with a certain unknown amount of chemical activity, the open-textured tuffs of both

basic and acid types, as well as the massive types of the same rocks, have been changed into highly schistose rocks, the degree of schistosity varying according to the original rock and other factors. The rocks have been mashed and their various constituent minerals elongated and flattened and compressed until in many instances the original texture of the rock has been almost completely destroyed.

MINERALOGICAL CHANGES.

Concomitant with the textural changes there have been profound mineralogical changes; original minerals have been completely replaced by other entirely different minerals; certain minerals have altered wholly or in part to other minerals, and minerals entirely foreign to the rocks have been brought in from outside sources and deposited in them. These changes have taken place on a large scale, and are characteristic of the whole district. They have all been discussed more or less fully in the detailed description of the rocks, pages 14-41, and to a less extent in the chapter on the origin and deposition of the ores, but it may not be amiss to give a brief summary of the subject in this chapter.

Each class of rocks, is, to a large extent, characterized by a type of alteration peculiar to itself. In the acid rocks, such as the quartz porphyry and the acid tuffs, and to a less extent the granite, many of the original minerals, especially the feldspars, have been destroyed and their places taken by sericite or kaolin. There are all degrees of sericitization depending upon the intensity of the forces producing the change, the end product being a quartz-sericite schist which shows nothing of the original characteristics of the rock from which it was derived. In these rocks there have been developed also small amounts of biotite, chlorite, and epidote, but these minerals are characteristic of the basic rather than the acid rocks.

The secondary minerals peculiar to the basic rocks, andesite, andesitic tuff, and the basic dike rocks, gabbro, diorite, and diabase, are chlorite, actinolite, epidote, zoisite, clinozoisite, calcite, and to a less extent biotite. As with the acid rocks, there are all degrees of alteration, the end product being a chlorite-epidote schist.

MINERALIZATION.

The formation of the veins and the deposition of the ores are considered as a part of the metamorphic process. As has been stated in discussing the veins and ores, it is believed that the material for the veins was largely,

and the ores were wholly, derived from sources outside the rocks in which they occur. If these assumptions are true, and all the evidence available strongly supports them, the formation of the veins and the deposition of the ores form, from an economic standpoint, the most important metamorphic event in the geologic history of the region. It is believed that the materials for the highly siliceous veins and the ores were derived from the great masses of granitic rocks that were intruded into the region long after the period of intense dynamic metamorphism was past, and that they were carried in solution, probably highly heated, and deposited in fractures in the basic schists. The veins are believed to have been formed by opening fractures, in part by dynamic forces associated with the intrusion of the granite masses, and in part by the linear force of the crystallizing quartz; and that they were considerably widened and enlarged by replacement of the wall rocks by vein matter and ore where the ore occurs in veins, and by ore where the ores are more or less disseminated in the wall rocks near the veins.

It appears to be clear from the study of such ore deposits as the Holloway and the Copper King mines, ore bodies in which the replacement of the wall rock has probably played an important rôle, that the character of the rock has been a very important factor in the development of the ore body. From such accounts of the Holloway ore body as were accessible to the writer, it seems to be established that some of the pinches and swells in this mine were determined by the character of the wall rock, which in this mine is variable. Where the wall rock was tuffaceous and more or less open textured the ore body is said to have been wide, but where the rock was dense and hard as is much of the porphyritic phase of the Virgilina greenstone the ore body is said to have been much narrower.

WEATHERING.

The only metamorphic process active at the present time is the superficial alteration of the rocks and ores known as weathering. By the term weathering is meant all the changes involved in the transformation of the rocks into soil. Under surface conditions the rocks are not stable and gradually disintegrate and decay until in the final stage they pass into soil. The processes involved in this transformation are both physical and chemical. The physical forces, important among which are expansion and contraction, and the expansion of ice formed during the winter when the water in the surface rock is alternately frozen and melted—are in large measure responsible for rock disintegration. The chemical reactions

involved produce hydration, oxidation, carbonation, and solution. The complex minerals are broken up into simple combinations, the soluble portions are removed and in the end all that remains of the solid rock is soil. The tendency is always from the unstable to the stable, and in the end only those combinations of elements remain which are stable under the prevailing physical and chemical conditions.

When decomposition proceeds more rapidly than erosion, the rocks become covered with a thick mantle of material which at the surface is soil, but which gradually becomes with depth the fresh unaltered rock. In such a region it is only in places in which erosion is very active, such as stream beds and steep slopes, that rock outcrops are found. Much of the Piedmont area of the Southern States is in this condition, and indeed the same is true of the greater portion of the Virgilina district, as shown on the accompanying map, Plate I.

Weathering affects the veins and ores just as it does the rocks. The massive vein matter, quartz and calcite, is broken up, the calcite taken into solution, and the insoluble quartz fragments are left behind in the soil. The ore minerals are also unstable, are attacked and broken down, the soluble portions removed, and the remaining portion, usually iron oxide, remains in the form of gossan. The process is rarely carried to completion in the Virgilina district, and, so far as data were available, the outcrops of the veins even at or very near the surface are marked by green and blue copper carbonate stainings instead of by porous masses of iron oxide or gossan associated with quartz. As a general rule, the order of alteration in vein outcrops is as follows: From surface to level of permanent ground water, leached and highly oxidized vein matter with little or none of the original ores remaining; from the level of ground water to the depth of more or less active circulation, a zone of primary ores more or less enriched by high grade secondary ore minerals; and, finally, below this zone and extending to the depth of mineralization, the ores as originally deposited. In the Virgilina district, the original ores are the rich sulphides, chalcocite and bornite, the veins are tight and the circulation in them apparently not very strong. Consequently, there is no marked middle or enriched zone in the veins. The important secondary ore minerals are chalcocite, cuprite, malachite, azurite, chrysocolla, and possibly tenorite, which with the exception of tenorite, are fairly plentiful in the oxidized portions of the veins.

GEOLOGIC HISTORY.

GENERAL STATEMENT.

In the chapter dealing with detailed description of the rocks, and that in which the structure and metamorphism were discussed, many factors bearing on the geologic history of the Virgilina district were considered in their relation to the subjects under discussion, but anything in the order of a connected story of the geologic development of the district would have been out of place in those chapters. Since the geology of the surrounding region has not been studied in detail, and the relationships of the different formations of the district and their areal extent is unknown, no attempt will be made to correlate them with any known and described formations. Furthermore, so far as observations have extended, all formations exposed in the Virgilina district below the Triassic sandstone are nonfossiliferous. These conditions make it unwise to attempt to locate in the geological column any of the formations except the Triassic sandstone and the diabase dikes accompanying it. All, therefore, that will be attempted will be statements showing as far as possible the origin of the different formations, their relation to each other, and brief discussions of the important geologic events in the history of the district, together with surmises as to the age of the different formations.

MICA AND HORNBLENDE GNEISS.

The oldest rocks of the Virgilina district are found on the extreme western border of the area mapped (Pl. I), and it is assumed that its history begins with the deposition or formation of those rocks, which are of two types, a well-defined mica or biotite gneiss, and a smaller amount of characteristic hornblende gneiss, each intimately associated with the other. As has been stated in the chapter on the detailed description of the rocks, these formations resemble very closely the Carolina gneiss and the Roan gneiss, respectively, and it may be possible that future work will establish the similarity. As has been proved in regard to the Carolina and Roan formations, it is believed that the mica gneiss of the Virgilina district represents the metamorphosed equivalent of a sedimentary formation, older than the hornblende gneiss, which is believed to be of igneous origin, and to have been intruded into the sedimentary formation before its metamorphism. It is believed that these gneiss formations are of pre-Cambrian age, and that they formed the basement upon which the volcano-sedimentary series were deposited.

IGNEOUS ACTIVITY.

There is no means of knowing the interval of time that elapsed between the metamorphism of the gneisses and the beginning of the igneous activity which formed the greater portion of the rocks of the district. But it is certain that the basement rocks had suffered intense metamorphism before the deposition of the volcano-sedimentary rocks.

The beginning of igneous activity was marked by the outpouring of acid or rhyolitic lava, associated with which was explosive volcanic activity on an enormous scale. This is the period that produced the material which now forms the mashed quartz porphyry, and acid tuff, and the sericite schists which are regarded as the same as the quartz porphyry and acid tuff, only more highly metamorphosed. It is impossible to picture the details of this and the following volcanic activity, but it is believed, from the wide and regular distribution of the rocks, to have been both of the fissure types of eruption, in which the lava broke through the already-formed rocks at numerous places throughout the whole region. After a great thickness of this material was piled up, it appears that the vulcanism in a measure subsided, and that there was a change in the type of ejectamenta from acid to basic—from rhyolite to andesite—and that during the first part of the outpouring of andesitic lava and tuff the volcanic activity was either slight or intermittent. These assumptions are based upon the fact that the lower part of the basic portion of the volcano-sedimentary rocks is in part of terrigenous origin—that is, it consists of basic volcanic material intermixed with varying amounts of land waste. In fact, some of the beds are nearly pure sandstone, and others are nearly straight conglomerate.

After an unknown period in which a great thickness of this volcano-terrigenous material was laid down, the vulcanism again appears to have become very active, and it appears that the ejectamenta became clean andesite and andesitic tuff. There is no way of even surmising the duration of this type of activity, but it certainly continued long enough for an enormous thickness of the andesite and andesitic tuff to be built up. The activity seems to have subsided gradually and somewhat in the same manner as it developed, since immediately overlying the clean andesite and andesitic tuff there is an enormous thickness of volcano-terrigenous material that can not in any way be distinguished from similar material built up immediately preceding the outpouring of the andesitic material.

The evidence as to the conditions under which these volcano-sedimentary rocks were deposited is not clear and conclusive. So far as observations have extended, the acid flows and tuffs appear to have been deposited

upon dry land. At least no clearly water-laid materials such as conglomerate and sandstone were recognized. On the other hand there is nothing to prove they were air-laid or to determine that they were not laid down under water.

When the volcano-terrigenous beds which immediately overlie the acid flows and tuffs are examined in detail it is clear that a large part if not all of the material was laid down under water. There are irregularly intercalated beds of more or less pure sandstone and numerous narrow bands of well-defined conglomerate, the pebbles of which are of well-rounded quartz, and the matrix of more or less pure, fine andesitic material. In fact, the matrix is apparently as fresh and unaltered as similar material in the straight andesitic tuffs, a fact which makes it clear that the material while clearly water-laid was transported only a short distance, and that it was not exposed to weathering agencies for a great length of time. The distribution of the sandy and conglomerate beds indicates an offshore or a flood-plain deposit. The fact that the conglomeratic and sandy beds occur in similar positions on each side of the area is regarded as evidence that the material was deposited in a shallow basin or an open arm of the sea. The latter hypothesis is regarded as the more probable of the two, since the series of volcano-sedimentary rocks increases greatly in areal extent toward the south.

The age of this volcanic activity is not known, and it has been considered by some, especially some of the early writers^a on the subject, as pre-Cambrian, while more recent students, as well as the first writer on the subject, Ebenezer Emmons,^b regard them as of early Paleozoic age. The most conclusive evidence on the subject is by Watson^c and Powell, in a description of a somewhat similar volcano-sedimentary series of rocks and slates lying northeast of the Virginia district. The slates are interbedded with the tuffaceous rocks, and contain early Paleozoic fossils. As the question stands at present there is not sufficient evidence to decide it, but it is believed that such as is available indicates that the vulcanism along the eastern border of the North American continent occurred in the early Paleozoic period.

^a Williams, George H.: The distribution of ancient volcanic rocks along the eastern border of the United States, Jour. of Geology, Vol. 2, 1894, pp. 1-31.

Nitze, H. B. C., and Hanna, Geo. B.: Gold deposits of North Carolina, N. C. Geol. Survey, Bull. 3, 1896, p. 37.

^b Geological report of the Midland counties of North Carolina, 1856, p. 41, *et seq.*

^c Watson, Thos. L., and Powell, S. L.: Fossil evidence of the age of the Virginia Piedmont slates, Amer. Jour. Sci. Ser. 4, Vol. 31, 1911, pp. 33-44.

CONSOLIDATION.

Regardless of the manner of deposition of the tuffaceous and sedimentary rocks, they must have been more or less consolidated before they could have been folded. It is believed that the process of consolidation was in progress during the deposition of the material, and that within a short time after the cessation of the volcanic activity the material had become fairly firm and solid rock. The fact that such a large portion of the series is water-laid makes it reasonably certain that the period of consolidation was short, since the cementation made possible by the presence of water would play an important part in the process and greatly hasten its completion.

FOLDING AND DEVELOPMENT OF SCHISTOSITY.

Following the consolidation of the rocks after an unknown interval, dynamic forces again became prominent, and the rocks of the district were thrown into closely compressed and for the most part overturned folds. The compressive force, as shown by the strike of the axes of the folds, acted in a northwest-southeast direction, and was so intense that not only were the rocks closely folded, but the process was continued until their original textures and structures were largely obliterated, and they were transformed into well-defined schists. It is probable that faulting may have accompanied the development of the folding, but, if so, the evidence of faults was either obliterated during the period of compression, or it was not recognized during the field studies in the district. It is also believed that much of the mineralogical alterations took place during the period of compression.

IGNEOUS INTRUSIONS.

It is believed that the interval between the folding and metamorphism of the volcano-sedimentary series and the intrusion of the granite and other rocks was a long one. One thing is certain, the rocks had been transformed into schists before the granite and other plutonic rocks now in the series came in. They are massive and show no indication of having suffered any dynamic metamorphism, facts which would be impossible if these rocks had been present in the series when it was compressed. There was no way of determining the relative age of the different intrusives except that the coarse-grained granite in the vicinity of Buffalo Lithia Springs is probably intrusive into the finer-textured granite at the same place. The intrusive rocks believed to belong to this period are granites of two types, a coarse-grained, in some instances decidedly porphyritic, and an even-granular,

fine-grained type; a coarse- to medium-textured gabbro, and small areas of diorite. From observations in areas of similar rocks outside the district, it is believed that the succession, beginning with the oldest, is diorite, granite, gabbro.^a It is believed that the earth movements attendant upon these intrusions formed the greater part of the joints that cut the schistose rocks, in many of which mineralized or unmineralized veins of the district were developed.

DEVELOPMENT OF THE VEINS AND DEPOSITION OF THE ORES.

Closely associated with the intrusion of the granite, probably immediately following it, came the solutions forming the numerous quartz veins, and deposited the ores in the fractures previously formed in the schistose andesitic rocks. The reasons for associating the formation of the veins and the deposition of the ores with the intrusion of the granite have been given in detail in the chapter on the origin and deposition of the ores (pp. 88-93), but it may not be amiss to summarize them briefly at this place. They are: (1) The veins are highly siliceous, containing 65 to 75 per cent silica; (2) the rocks in which they occur are decidedly basic; (3) the ores and vein filling were derived from a source outside the rocks in which they occur and being siliceous they must be genetically associated with acid rocks; (4) the time of formation of veins and deposition of ores, so far as it could be determined, is approximately that of the intrusion of the granite; (5) the granite is the only acid igneous rock known in the district which could satisfy the conditions previously stated, and it is therefore believed to have been the source, or at least its intrusion opened up the source, from which the ores and vein fillings were derived. So far as observations have extended, there is no way of fixing the age of the vein formation and the ore deposition. The veins and ores show absolutely no indication of having suffered regional metamorphism, and on this account they must have been formed subsequent to any of the periods of important earth movements in the region. The last of these was the revolution at the close of Carboniferous time, and it seems to be clear that the ores were deposited some time since the close of this period, but further than this no surmises are possible with any degree of fact. What was going on in the district between the close of the ore deposition and the deposition of the Triassic sandstone is unknown. It is believed, however, that for a long period preceding Triassic time the district was under erosion.

^a Laney, F. B.: The Gold Hill mining district of North Carolina, N. C. Geol. Survey. Bull. 21, 1910, pp. 73-74.

TRIASSIC SANDSTONE AND DIABASE DIKES.

The first geologic event of known age in the Virgilina district is the deposition of the red sandstone, a patch of which occurs in the western boundary of the portion included in the accompanying map (Pl. I), near Wolftrap station on the Richmond and Danville branch of the Southern Railway. This occurred during Triassic time, and shows that at least a portion of the district was under water, probably the bottom of a narrow arm of the sea at that time. It is not known how much of the district was covered by the Triassic sandstone, for all that remains of this formation at present is the little patch just referred to. Near the close of Triassic time occurred the intrusion of many diabase dikes into the rocks of the district. While these dikes are not numerous they are well distributed throughout the district and the surrounding region. At least two mines in the district, the Durgy and the Blue Wing, have disclosed such dikes, and in both instances it is perfectly clear that the dikes are younger than the veins and ores.

EROSION AND WEATHERING.

From the close of Triassic time all factors indicate that for the most part the Virgilina district has been under constant weathering and erosion. So active have been the agencies of erosion, that notwithstanding the fact that the region was reduced practically to base level during Cretaceous time, and then rejuvenated by uplift, it is again, from a physiographic point of view, in old age. The agencies of erosion are yet active, but the relief of the district is so subdued that weathering is more active than erosion, and, as a consequence, except in a few places, the rocks are deeply covered with soil derived from their own disintegration and decomposition.

PHYSIOGRAPHY.

The southeastern portion of the United States presents three distinct types of topography, each occupying a distinct area. These physiographic provinces, beginning at the coast and extending westward, have been named the Coastal Plain, the Piedmont Plateau, and the Appalachian Mountains.

The Coastal Plain occupies the area extending from the shoreline westward to an abrupt rise in elevation of the land known as the "Fall Line," which has a trend roughly parallel with the coast line. The belt as a whole is a rather monotonous plain without prominent elevations. Geologically it is made up of Cretaceous and younger sedimentary rocks, including much partially consolidated material.

Beginning at the "Fall Line" and extending westward to the foot of the Blue Ridge is a belt of moderate elevation—300 to 700 feet above mean sea-level. Relief is moderate and the general appearance is that of a moderately level region diversified with low-lying, well-rounded hills, and gently sloping valleys. The streams are fairly well graded and are not on the whole very swift-flowing. The rocks are for the most part of Paleozoic and pre-Cambrian age, and are of both igneous and sedimentary origin. They have suffered intense dynamic metamorphism, which has changed them for the most part more or less completely into schists and gneisses. The region has long been subjected to weathering and erosion, and for the most part the rocks are deeply covered with a thick mantle of soil and more or less completely disintegrated and decomposed rock. The region is regarded as the stumps of an ancient range of mountains which have been worn away by long periods of weathering and erosion. This belt or province is known as the Piedmont Plateau.

West of the Piedmont Plateau are the Appalachian Mountains, a region of rugged topography, long mountain ranges with many spurs, and steep, oftentimes precipitous, slopes, which comprise the highest mountain peaks east of the Rockies. The valleys are for the most part narrow. The streams have steep gradients and are consequently swift-flowing. The rocks are of Paleozoic and pre-Cambrian age, and are of igneous and sedimentary origin. For the most part they have suffered intense metamorphism which changed them into various types of slates, schists, and gneisses.

The Virginia district lies wholly within the Piedmont Plateau, and its surface features conform to those of the province in general.

Relief.

It is not possible to discuss the surface features in detail or very accurately without a topographic map, which unfortunately is not available. The statements here made must, therefore, be regarded as only approximately accurate. However, the U. S. Geological Survey in coöperation with the State Survey has run the lines of primary levels for the district, which gives the elevation of a few places accurately. The levels were run along the railroad from Clarksville to Denniston Junction, thence to South Boston, to Keysville and to Buffalo Junction and along Dan River from South Boston to Clarksville. The elevation of the town of Virginia is 516.1 feet.

The topography of the district is to a large extent determined by the character of the underlying rocks. This is especially true of the Virginia

• greenstone. These rocks make up the Virgilina ridge, which attains the highest elevation within the district, and which is its most striking surface feature. This ridge, while it is flat-topped, low-lying, and has very gentle slopes except where intersected by streams, forms the watershed of the district, and extends with considerable prominence through a good part of its length. It is said to extend with more or less prominence from Dan River to about 30 miles south of the state line. The most prominent portion reaches from Dan River to 5 or 6 miles south of the state line, and the part showing the greatest relief and most rugged topography is near the High Hill mine, where Hyco River crosses the ridge. The ridge is made up of the andesite and andesitic tuffs with their included terrigenous material, and its boundaries roughly delimit these formations.

Aside from the ridge, the district possesses nothing more important in the way of relief than low-lying, well-rounded hills. The large granite area in the vicinity of Redoak post-office has sufficient elevation above the surrounding country to form a low-lying, dome-like hill, deeply scored by streams, the highest portion of which is near the center of the area. Taking the district as a whole, the only prominent relief or rugged topography is along the more important stream courses, south of but including Dan River. Hyco River, Blue Wing and Aaron's creeks present fairly rugged topography along the lower portions of their courses.

Drainage.

The Dan and Roanoke rivers form the master streams of the district. Dan River crosses the district near its middle in a nearly east-west direction, while the Roanoke crosses it in a nearly southeast direction, and unites with the Dan to form the Roanoke a short distance east of the limits of the district as mapped. These streams and two others, Bannister and Hyco rivers, are antecedent streams and hold their courses irrespective of the rocks over which they flow. The courses of the other streams have been determined to a great extent if not wholly by the character of the underlying rocks, and are therefore consequent streams.

This indicates that the four rivers are perhaps older than the present topography and are, as it were, superimposed upon it, while all the other streams are flowing in courses determined largely by the nature of the rocks, and have therefore developed with and as a part of the present topography. These major streams have developed a surface configuration which in a great measure controls the direction of flow of the numerous

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small streams. Many of the streams in the district have considerable fall in their courses and, as a consequence, flow fairly swiftly; in fact some of them in the more rugged portions of the district become roaring, rushing torrents after heavy summer rains. The larger streams also, during the rainy seasons of late spring and early summer, often overflow their banks and inundate considerable portions of the valleys through which they flow.

Erosion is rapid in the region, and little or no attempt is made on the part of the people to prevent excessive land wastage by control of forest fires and by grassing the land areas most susceptible to wash. As a result much of the soil is washed into the streams, which especially during the rainy seasons carry heavy burdens of sediment, and as a consequence, a great deal of the land is depleted and very lean.

Physiographic History.

A detailed examination of the present surface, in its relation to the underlying rocks and the relation of the present drainage systems to the geologic formations as well as to each other, offers certain indications of previous physiographic conditions of the Virginia district.

A close consideration of these facts makes it possible with some degree of probability to make a few statements and surmises as to the physiographic history of the district. The surface features of a region have not come into their present form and conditions by mere accident, but have been governed by certain laws and conditions. The rate at which a stream deepens and modifies its channel depends upon many items, among which may be mentioned precipitation, gradient, character of formations over which it flows, and these in turn are dependent upon the ever-varying geologic conditions of the region. Each major type of surface has its own peculiar type of drainage, and as the surface features are changed by any geologic process, the drainage likewise changes and accommodates itself to the new conditions. One change does not always, nor usually, for that matter, completely obliterate the features of the previous cycle, remnants of which can almost always be recognized upon close examination. While it will be by no means possible to trace the physiographic history back to the beginning, it will be possible to enumerate a few of the most important items.

The nature of the rocks making up the greatest part of the Virginia district—volcanic flows, volcanic tuffs with which in places are large amounts of terrigenous material, sands, and water-worn pebbles, is clear evidence that at the time of deposition the area was low-lying and in part

at least, under water—probably offshore or estuary conditions. After an enormous thickness of the volcano-sedimentary material had been built up, conditions changed and the region was uplifted high above the sea, probably into a mountain range. The closely folded, highly metamorphosed condition of the rocks is strong evidence for this assumption. Erosion then became active and a system of drainage was established, but what relation this drainage bore to the present system it is not possible to state. That the region was finally worn down to a comparatively level surface, and then submerged in part at least below the sea, is shown by the areas of red and brown sandstone of Triassic age which are found in the region and in one small area in the district. What the physiographic features were during Triassic times one can only surmise. That there was a well-established drainage system, and that at least a part of the district was submerged below the sea are certain, but there is no way of determining the location of the streams nor of knowing how much of the district was submerged.

It seems probable that the present drainage system has established itself since the close of Triassic time, but at what period following this time the master streams assumed their present courses is not known. It is certain, however, that Dan and Roanoke rivers and possibly the Hyco assumed approximately their present courses prior to the elevation of the district with which the present creeks and smaller streams are associated.

These conclusions are justified by the fact that the rivers follow courses contrary to or regardless of the present topography and geologic structure of the district. Their courses are largely, if not wholly, independent of the rock structure of the district, while the courses of the smaller streams have been determined in a large measure, if not wholly, by the geologic structure and the character of the formations over which they flow.

It appears, therefore, that the large streams had assumed their courses prior to the last uplift of the district and that they have been able to wear down their channels as rapidly as the country was uplifted, and thus that to-day these streams have courses that are genetically related to previous surface conditions rather than to the present, as are the smaller streams.

DETAILED DESCRIPTION OF THE VEINS AND ORES.

VEINS.

General statement.—The veins of the Virgilina district are typical fissure veins. With the exception of a few mineralized areas in more or less epidotized portions or zones of the true basic schist, the ore deposits

all occur in well-defined veins in which quartz is by far the predominant mineral. Calcite, epidote, chlorite, in a few instances small amounts of plagioclase, probably albite, and in some instances a little orthoclase, are present in varying amount. These veins occur in fractures—in some instances possibly fault planes—which, taken as a whole have a more northerly trend than the schistosity of the country rock, which averages about 30 degrees east of north. The majority of the veins have trends varying from 30 degrees east to 10 degrees west of north, while a few—the so-called cross-courses—vary from 10 to 45 degrees west of north. Almost every vein, except the “cross-courses,” throughout some part of its length follows the schistosity of the country rock. After following the schistosity for varying distances, the vein is noted to assume at once a more northerly trend, usually only a few degrees, than the schistosity. This course will be held also for varying distances when it again assumes the trend of the schistosity, the same being repeated again and again. This feature of the veins offers strong evidence in favor of the hypothesis that the formation of the veins is a comparatively recent geologic event, and that prior to their formation the country rocks had been altered into schists and were in much the same condition that they are at present. If such were the case it would be quite normal for the shearing forces to relieve themselves in part along the parting planes of the schists, which are always lines of weakness. Thus any line of stress differing in direction from the trend of the schistosity only a few degrees would normally, in part at least, be relieved by shearing in the planes of greatest weakness in the country rock, that is, in the planes of schistosity. The veins are usually not continuous for long distances, but in a few instances a single vein may be traced either by the outcrop or continuous quartz débris for distances varying from one to two miles, and in one case the so-called Mother Lode vein was traced by outcrop or almost continuous quartz débris for nearly three and one-half miles. All veins of the district have characteristic peculiarities, such as “pinches” and “swells” both linearly and vertically, which tend to give them the appearance of numerous connected quartz lenses. In fact, in many instances the lenses are disconnected, and in others they are joined together only by a mere stringer of quartz. In other cases the fractures are apparently continuous for longer distances than the veins show them to be. In such cases vein matter has been developed only at irregular intervals in the fissures. These peculiarities have a practical application in doing development work, in that even though the vein pinches to very narrow limits, or is lost altogether, the fracture in which it



(A) Typical outcrop of a large but barren quartz vein near High Hill mine. Few veins outcrop as prominently as this one.



(B) Typical but barren vein exposed in railroad cut near Christie, Va. The irregularities shown by this vein, such as "pinches" and "swells" and lenticular form, are characteristic of all veins that have been opened in the district.

developed remains, thus giving the miner the walls of his vein which he can follow with some assurance that they may open again and more vein matter come in.

It is rare that an important vein fails to present some kind of an outcrop at some place along its course, but in a few instances small veins which had no surface outcrop have been exposed by cross-cutting and other development work. Also in many instances a well-defined vein will, at many places in its course, show no outcrop beyond a very small or insignificant amount of quartz débris on the surface. As a general rule, vein outcrops are rare and are found only where the vein happens to be exceptionally large or the topography very favorable for outcrops, such as steep-hill slopes or a stream or road cutting. The common and also unmistakable indication of a vein is the great number of quartz fragments marking on the surface of the ground the course of the vein. The usual outcrop consists of a ledge of irregular quartz boulders varying in size from a few inches up to several feet in diameter. A typical outcrop is illustrated in Plate IV (A).

Very few of the workable mineralized veins in the district are more than 10 feet wide, and the average width is about 3 feet. That they are numerous is shown by the large quantity of quartz débris which is found in greater or less abundance everywhere. As opened by mining the veins in general have well-defined walls which part readily from the vein in mining, although the mineralization is not confined exclusively to the vein, a small, but often important amount of ore occurring in the schist at the contact with the vein. In many instances numerous fragments and plates of country rock are included within the vein. This is so marked in some cases that it gives the vein a banded or brecciated appearance. The former especially is true at the High Hill and Blue Wing mines and to a less extent at the Durgy mine. At the last-mentioned mine in addition to the pseudo-banding, about 100 feet north of the shaft, on the 335-foot level the vein was split and included a "horse" of country rock in the form of a lens about 25 feet thick and 75 to 100 feet long. All the mines show numerous more or less altered angular fragments of the country rock, indicating that there must have been more or less brecciation when the fractures were formed. The dump at the Thomas mine shows more of such included fragments than any other mine in the district. In all such cases some of the fragments and plates of country rock included in the vein show evidence of metasomatic replacement in that they are in many instances more or less completely altered to quartz. This phenomenon is especially well shown in the Blue Wing vein. The

quartz thus formed generally has a decided blue or dirty gray color and contrasts strongly with the clean vitreous white quartz of the vein. In many instances near one of the walls a vein will consist of thin layers of quartz interleaved with similar layers or plates of schist, indicating that at the time the fracture was formed the schists were rifted or torn apart along the planes of schistosity, and that the vein matter had been subsequently deposited in the rifts.

In some mines, especially the Durgy and the Blue Wing, the walls at the contact with the vein in many places are very smooth and closely resemble slicken-sided surfaces. Such, indeed, may be the case, since it is not at all unlikely that there was considerable movement at the time the fissures were formed, or even since that time. Where there are no slicken-sides nor even any indication of them, the contact between vein and wall is generally clear-cut and sharp, and there are no very evident indications of replacement of wall rock by quartz and other vein matter. The only change at the contact is a kind of dark-colored chloritic material somewhat resembling altered schist, which in places wraps the vein. Weed speaks of this feature as being prominent at the Holloway vein, and describes it as a micaceous wrapping probably derived from the country rock.

Only a small percentage of the veins are mineralized, and they are almost exclusively confined to the Virgilina greenstone. With the exception of the Kay mine, every prospect opened to any important extent in the district is in a vein in the greenstone. About the only way in which the barren veins differ from those that contain the ores is in the fact that the ore minerals are lacking. Possibly calcite and epidote are also less plentiful in the barren veins, and feldspar and in places hematite are equally if not more abundant. So far as is known the quartz of the barren vein is similar in all respects to that in the veins which carry values. The veins at the different mines have been described in detail under the descriptions of the respective mines, and since this chapter is confined to descriptions of the veins as a class and to generalizations in regard to them, these descriptions will not be repeated here.

It may be noted that, if upon the accompanying geological map, Plate I, a line be drawn approximately 30 degrees east of north from the Duke mine, it will pass through or very near the following mines and prospects: The Cross Cut prospect, the Durgy mine, the Northeast prospect, the Copper World mine, the Gillis mine, the Thomas mine, the Holloway mine, and the Blue Wing mine. Thus this line forms, as it were, an axis along which practically all the developed mines of the North Carolina portion of

the district lie. It may also be noted that a second, but so far as developed at present, a secondary axis or zone of mineralization, is located about three-fourths of a mile northwest of the main axis and runs parallel with it. The ores of the main axis are those characteristic of the Virgilina district and consist of bornite and chalcocite in the usual quartz-epidote-calcite gangue, while that of the second includes the native copper deposits of the Catoctin type.

The writer freely confesses that thus far he has not been able to find a satisfactory cause for the relationships just described. Several factors suggest themselves as possibly having a bearing on the subject, among which may be mentioned the following: The mineralization may be associated genetically with certain phases of the Virgilina greenstone and consequently is found only where these phases of the rock occur. Or on the other hand, the mineralized bands or zones may represent lines or zones of deep fracturing and faulting which opened channels through which the mineralizing solutions came into the greenstone from an entirely outside source. The first hypothesis appears to fail because of the fact that, so far as could be determined, the greenstone of the mineralized zones does not in any way differ petrographically from that outside of these zones. Many factors seem to sustain the theory that the mineralized bands or zones represent lines of deep fracturing and it is, therefore, offered as a tentative explanation of the phenomena.

NATIVE COPPER DEPOSITS.

The deposits of native copper and cuprite in epidotized portions or zones of the country rock, while not occurring in veins, should be considered in this chapter. Thus far these deposits have amounted to very little from a commercial standpoint, but to the student of ore deposits they are very important, and of course, there is a possibility that such a deposit on a large enough scale to be worked on a commercial basis may be discovered. These native copper deposits are included by Weed^a in his "Catoctin type."

The writer had little opportunity to study this type of deposit, there being only one small prospect in the native copper zone in operation at the time of the field examinations. Because of this, details were not obtainable and but little in the way of generalization can be given. Thus far only a few openings have been made in this type of deposit, and these have been for the most part confined to a narrow zone beginning at the southern

^a Weed, Walter H.: Types of copper deposits in the Southern United States, Trans. Am. Inst. Min. Eng., Vol. 30, 1900, p. 452.

limits of the town of Virgilina and extending perhaps two miles southwestward. So far as noted there is no vein and no typical gangue minerals, unless the epidote and quartz be so regarded, and the copper occurs in the metallic state as small grains and small irregular areas in the highly silicified and epidotized areas or zones in the country rock. Unlike the vein deposits, in linear extension they appear invariably to follow the trend of the schistosity of the country rock. The native copper so far as noted is confined to areas of epidote, and in most instances in quartz stringers and areas in the epidotized schists, suggesting that the solutions which produced the alterations in the country rock also brought in the copper. It may also be further suggested that the fracturing was not extensive enough to permit the formation of the usual vein, the schists having been only sufficiently torn apart to permit copper-bearing solutions to circulate to a limited extent through them. This, however, does not throw any light on the question as to why the copper should have been deposited in the metallic state instead of as sulphides, as in the quartz veins. It might be suggested that ferrous iron in the minerals of the country rock may have caused it. It is known that minerals, even silicates, rich in ferrous iron may, under certain conditions, reduce copper in solutions to the metallic state.

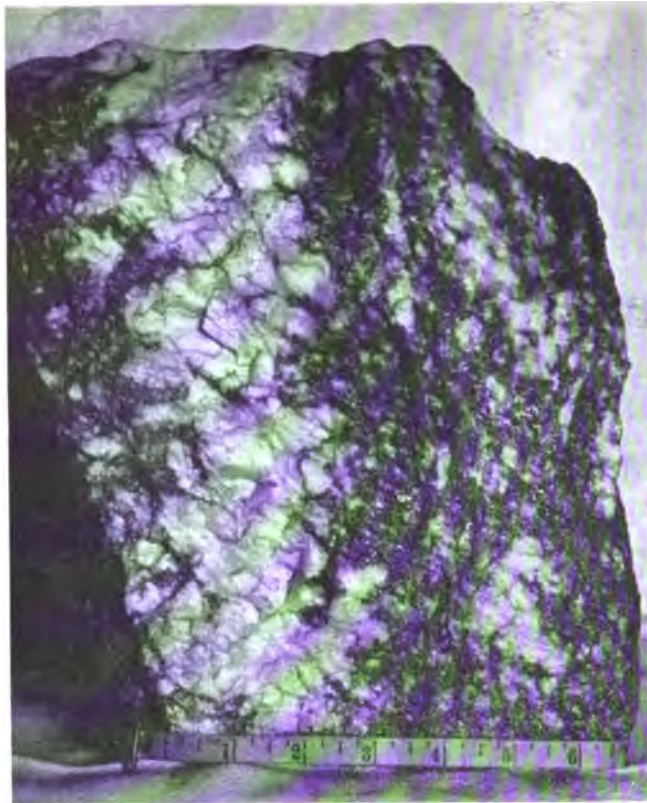
In a few instances native copper was noted in amygdules in epidotized schist derived from areas of amygdaloidal andesite intercalated in the tuffs.

The cuprite which occurs in this type of deposit is not confined to the epidote and quartz, but is found in the parting planes of the schists near the native copper in epidote. In some instances small areas were noted in the quartz and epidote, filling spaces that had once been filled with native copper. Other areas were seen in which a core of copper still remained. The cuprite is believed to be of supergene or secondary origin and to have been derived from the native copper.

MINERALOGY OF THE VEINS.

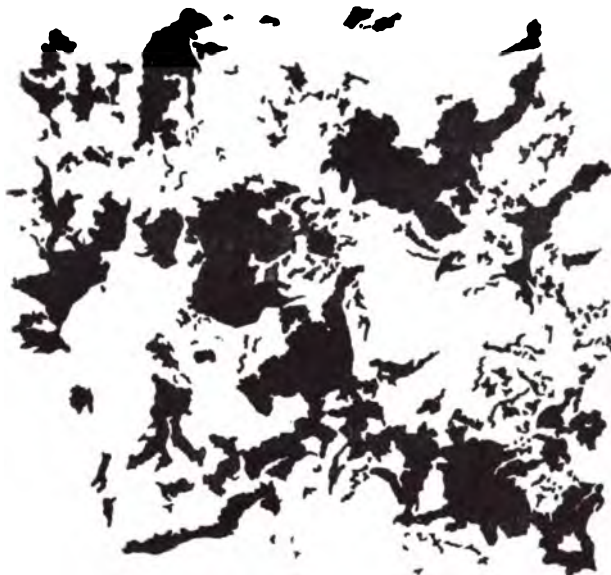
General statement.—The gangue minerals of the veins, exclusive of included fragments of schist, named in the approximate order of their abundance are: Quartz, calcite, epidote, chlorite, hematite, sericite, albite, and possibly other plagioclase feldspars in small amount, and pink orthoclase.

The ore minerals named in the approximate order of their abundance are: Bornite, chalcocite, native copper, malachite, azurite, cuprite, chalcopyrite, chrysocolla, klaprothite (?), pyrite, argentite, silver, and gold. Of these minerals, bornite (in part), chalcocite (in part), chalcopyrite (in



(A) Photograph of a specimen of ore from the Wall mine showing the relation of ore and gangue. The vein was divided at the point from which this specimen was taken, and the piece here figured represents the entire width of one portion of the vein.

Dark areas = ore, chalcocite and bornite. Light areas = vein matter, largely quartz.



(B) Tracing made from a polished surface of a specimen of ore from the Wall mine, natural size. Shows the relation of the ore to the quartz gangue. This relationship is typical of all the mines in the district. The ore and quartz appear to be of contemporaneous deposition.

Black = ore, chalcocite and bornite. White = gangue, largely quartz.

part), pyrite, klaprothite, argentite, copper in the native copper deposits, and gold are regarded as hypogene or primary, while a part each of the chalcocite, bornite, and chalcopyrite, and all the native silver, cuprite, malachite, azurite, and chrysocolla are supergene or secondary.

From these statements it can be seen that the mineralogy of the veins of the Virgilina district is simple, there being few rare or complex minerals. The gangue minerals and the hypogene ore minerals are so intricately intermixed and intergrown that there is little doubt of all being contemporaneous in development. Typical relations between ore and gangue are shown in Plate V.

DETAILED DESCRIPTION OF GANGUE MINERALS.

Quartz.—The ores as they occur in the ore shoots that have been opened contain an average of $2\frac{1}{2}$ to 3 per cent of copper, and carry an excess of from 70 to more than 75 per cent silica. The veins taken as a whole will carry a much higher percentage of silica. This shows at a glance that the veins must be made up largely of quartz.

The quartz of the veins is for the most part of the white vitreous variety, quite massive, and, while completely crystalline, rarely occurs in the form of crystals. As a rule it is very solid and dense and only in very rare instances does it show honeycomb structure. In a few places, notably in an abandoned field about 3 miles north of Virgilina, well-terminated crystals were found in the quartz débris on the surface. Only one end of the crystals showed perfect terminations, the other being broken or irregular, making it appear as if the crystals had formed with their points projecting into cavities. The forms on the crystals are simple, only common prism and pyramid faces having been noted. Crystals at this point were fairly numerous. They were peculiar in one respect, being made up of zones of clear transparent quartz alternating with others of white or milky appearance. At the Seaboard mine and to a less extent at the other mines quartz occasionally occurs as poorly terminated or rounded crystals which in some instances project into the larger masses of ore. As a rule the faces of such crystals are not well developed and they closely resemble rounded pebbles. Well-terminated quartz crystals occur in small openings or vugs associated with calcite crystals in the High Hill mine. Many fragments of the schists occur as inclusions in the veins, and in a few instances some of these were partially replaced by quartz. In many cases they have sharp and clear-cut boundaries and show little or no indications of metasomatism. The primary ores and all other minerals in the veins are inti-

mately and intricately intergrown with the quartz, which makes up from 50 to over 75 per cent of the veins.

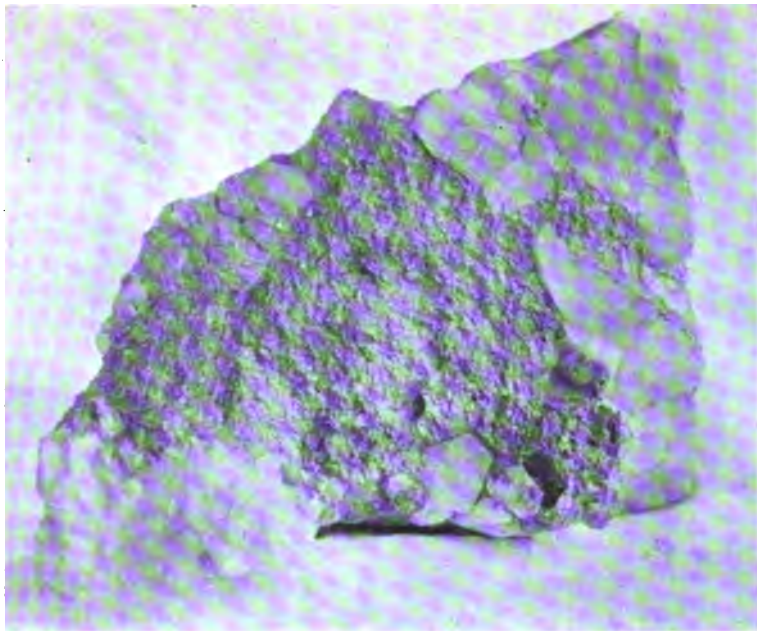
Calcite.—Calcite is next in importance to quartz. It occurs regularly in all the veins that have been opened, but is more abundant in some mines than in others. The Blue Wing vein contains much more of this mineral than any other mine in the district. It is massive, crystalline, and irregularly distributed through and intergrown with the quartz. This in fact is typical of the occurrence of calcite in all the veins. Very rarely is it found in crystals as in the High Hill mine, where small vugs are lined with well-terminated quartz and calcite crystals. Pogue^a describes two types of calcite crystals from the High Hill mine, one type consisting of a combination of the positive rhombohedron $r(10\bar{1}1)$ and the rare scalenohedron $G:(\bar{7}2\bar{9}5)$, and the other of a symmetrical combination of the scalenohedron $Y(32\bar{5}1)$ and the negative rhombohedron $e(01\bar{1}2)$ modified by the positive rhombohedrons $r(10\bar{1}1)$ and $k(50\bar{5}2)$, and the rare scalenohedron $G:(\bar{7}2\bar{9}5)$.

In the Seaboard and Copper King mines calcite crystals occur with poorly developed faces. They are associated with quartz, epidote, albite in good crystals, and the ores. In ore from the Copper King mine copper crystals are occasionally found projecting into masses of bornite and chalcocite. (See p. 157.)

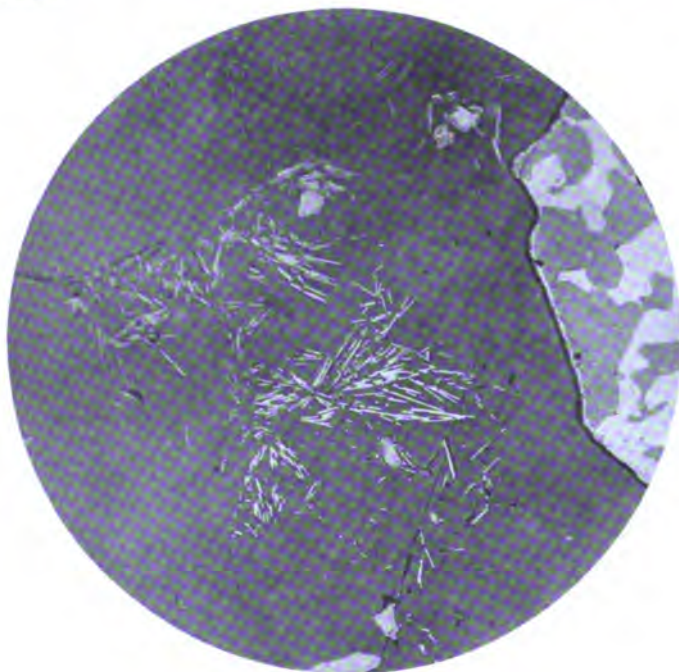
Calcite as it usually occurs is massive and intimately intergrown with the quartz in such manner as to make it clear that the two minerals are contemporaneous in development. The ore minerals occasionally occur in the massive white calcite in the same manner as they are found in the quartz. Very little calcite was noted in the veins in which the predominant values lie in gold; however, it is present to some extent in the Red Bank vein. (See p. 161 for description.)

Epidote.—Epidote as it occurs in the veins possesses only its usual and normal characteristics, and is generally intimately intergrown with the quartz and rarely with the calcite. Where abundant it carries the sulphides as do the quartz and calcite. The color is the usual pistachio green, and its texture is generally granular, rarely in well-terminated crystals. In some places, especially in the native copper deposits, epidote and quartz occur in alternating bands. In such instances the epidote is always granular. It rarely or never occurs in crystal form.

^a Pogue, J. E.: Crystallographic notes on calcite, Smithsonian Miscellaneous Collections, Vol. 52, 1909, Pt. 4, pp. 467-468.



(A) Photograph, natural size, of a specimen of ore from the Copper King mine showing association of ore (chalcocite and bornite) and calcite. Some of the calcite which is imbedded in the sulphides is in the form of well-terminated crystals.



5mm

(B) Photomicrograph of a polished section of ore from Blue Wing mine showing plates of hematite in quartz. Hematite occurs in both sulphides as well as in the rocks and gangue minerals of the district. An area of intergrown bornite and chalcocite is shown on one side of the figure, and a few small areas of chalcocite occur in the quartz.

White = hematite. Light gray = chalcocite. Darker gray = bornite.
Darkest gray = quartz.

Chlorite.—Chlorite is an abundant gangue mineral in all the mines, but is more plentiful in some than in others. It possesses only its normal characteristics, is generally dark green in color, and is likely to be found in masses made up of tufts or bunches which show an aggregate polarization effect somewhat similar to that of chalcedony. In some instances the chlorite might be confused with sericite when the two occur in the same section. They may be distinguished from each other by noting the facts that chlorite is almost invariably a rather dark green in color, that it does not show the change in relief when rotated on the stage of the microscope which is characteristic of sericite, and that it always has its characteristic low birefringence. In a few places, especially in some of the ore from the Copper King mine, in which the mineral is very abundant, chlorite is intimately associated with the sulphides, and appears, in some instances, to have been replaced by them. However, in the specimens of this type that were studied, the evidence was not conclusive, and it is not certain that chlorite and sulphides were not of contemporaneous deposition.

Hematite.—Micaceous hematite, or specularite, as it is sometimes called, is present as a gangue mineral in all the mines of the district. For the most part it is present only in small amount, but in some places it is more abundant than the sulphides. This is especially true of a small prospect about half a mile southeast of the Blue Wing mine in which hematite makes up more than 60 per cent of the metallic minerals of the vein as shown in the material on the dump. In many instances the quartz of the gangue is literally filled with minute plates of hematite. A typical area of this kind is shown in Plate VI (B). In addition to its prominent place as a gangue mineral, hematite is also widely distributed throughout the country rock.

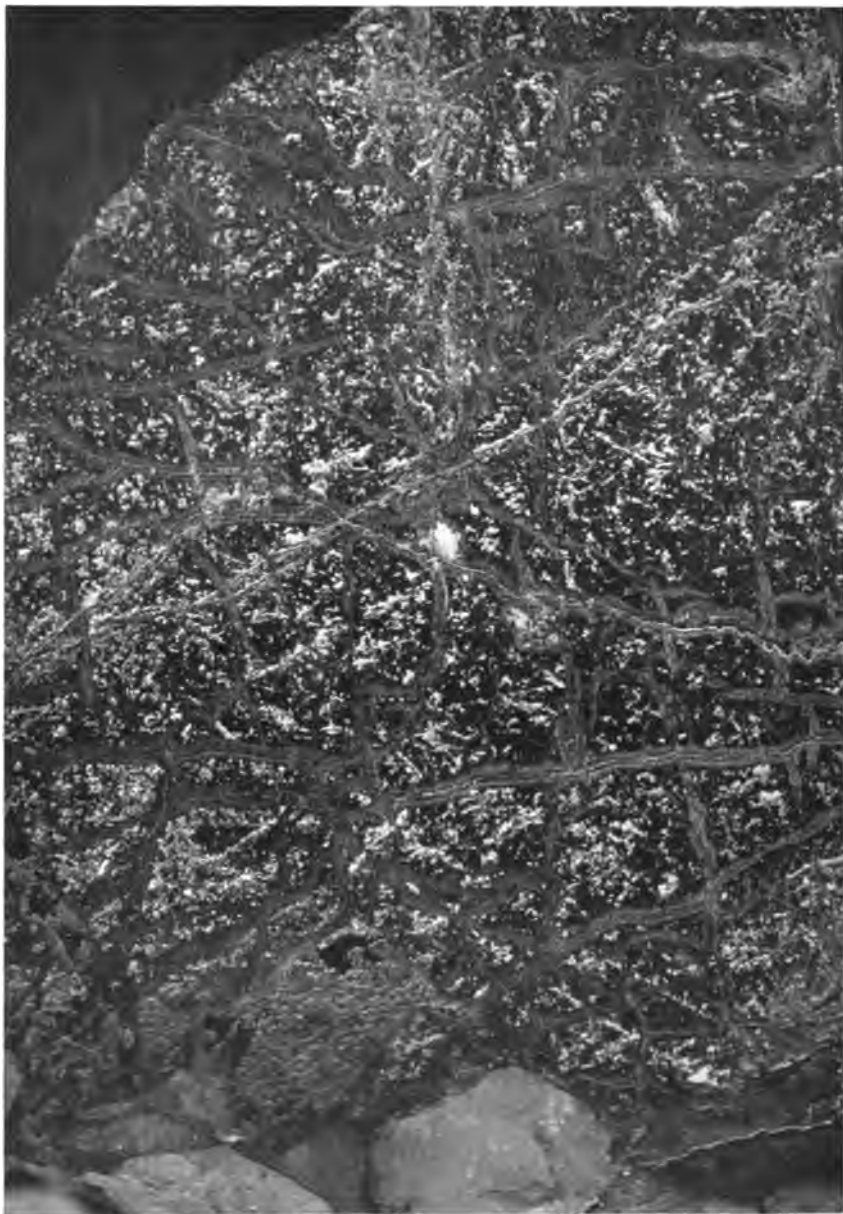
Sericite.—Another of the persistent gangue minerals, and one which is present in appreciable amount, is sericite. Almost any section of the ores and gangue from any mine in the district will show sericite very intimately associated with the sulphides. It occurs both as masses projecting from the other gangue minerals into the sulphides and as irregular bunches of crystals included within them. So far as the writer's observations have extended, the relation of the sericite to the sulphides does not warrant any positive statement as to the relative age of the two. He is inclined, however, to regard them as of contemporaneous deposition. The rôle of sericite as a gangue mineral has recently been studied in much detail by Rogers,^a who,

^a Rogers, Austin F.: Sericite, a low temperature hydrothermal mineral, *Economic Geology*, Vol. 11, 1916, pp. 118-150.

after an examination of a number of polished and thin sections of the Virgilina ores, comes to the conclusion that the sericite is later than the hypogene chalcocite and the bornite, but earlier than the supergene chalcocite. The article is illustrated with photomicrographs of polished sections of ore specimens from the Durgy and the Blue Wing mines, which Professor Rogers interprets as showing that the sericite is younger than the hypogene but older than the supergene sulphides. The writer, after a very careful study of many polished sections as well as many thin sections of the Virgilina ores and also a careful study of Professor Rogers' photographs, believes that the evidence presented by the ore sections is not conclusive, and that it points more strongly toward a conclusion that the sericite is contemporaneous with the hypogene sulphides.

Albite.—Albite, and possibly other plagioclase feldspars, is of frequent occurrence as a gangue mineral in the Virgilina ores. It usually occurs as well-developed crystals which vary in size from one-fourth of an inch to one inch in longest direction. It is intimately associated with quartz, chlorite, calcite, and the hypogene sulphides. In the Copper King mine albite occurs plentifully in well-formed crystals in massive sulphides which appear to have replaced chlorite, and the same hand specimen occasionally shows albite, quartz, and calcite in close association with the sulphides. It occurs in the Seaboard mine (shaft No. 3), with quartz, calcite, epidote, and the hypogene sulphides. It is also present in small amount in all the other mines of the district, but was not found in such intimate relations with the sulphides as in the mines just mentioned. In many of the prospect openings made in different barren veins in the district, albite is very abundant. This is especially true of an abandoned prospect in an old field about one-fourth of a mile southwest of the store at Red Bank. In the material on the dump at this place a cream-colored feldspar, probably albite, is second in abundance as a gangue mineral only to quartz. In the Red Bank gold mine albite and a delicate pink feldspar, probably orthoclase, occur frequently in stringers and veinlets in the ore and in the associated rock.

Orthoclase.—A delicate pink or flesh-colored feldspar, which, so far as methods of identification could determine, in the absence of chemical analyses, is orthoclase, which is found as a gangue mineral in the Holloway, Durgy, and Blue Wing mines, and in considerable amount in the two Cornfield prospects just south of Virgilina. In the first-mentioned places the mineral was not found in actual contact with the ores, but in the Cornfield prospects it serves as a host mineral for all the different hypogene sulphides.



Photograph of a polished surface of ore from the Seaboard mine, x10. This specimen shows a mass of bornite penetrated in all directions by a mesh or network of chalcocite which has formed in fractures in the bornite. This type of chalcocite is clearly of supergene origin and is typical of all such chalcocite examined, the only difference being the stage of development. This one is farther advanced than any of the others shown in this report. The line in the center of many of the chalcocite veinlets is quartz and marks the position of the fracture in which the chalcocite began to develop. Running diagonally across the specimen is a more recent fracture which cuts both bornite and chalcocite veins. A tiny veinlet of chalcocite has formed in this fracture.

It frequently occurs in the form of small veins or stringers in the country rock in the vicinity of the veins. It is also fairly abundant in the Red Bank gold mine, occurring in a similar manner to that in the other mines. The occurrence of orthoclase as a gangue mineral in the ore deposits is of considerable importance in considering the question of the origin of the ores and the solutions which deposited them. So far as is known orthoclase does not occur as an original mineral in the Virgilina greenstone. The discovery of it in appreciable amounts in the ore deposits, therefore, is strong evidence in favor of the belief that the ores and the solutions depositing them were derived from a source or sources entirely outside of the greenstone, and in all probability from a granitic rock. No such rock except the Redoak and Buffalo granites is known in the district, and it is therefore believed that the ore deposits are genetically related to the granite and that they were formed contemporaneously with the intrusion of the granite masses, or immediately following the intrusion while the magma was cooling and giving off its emanations.

DETAILED DESCRIPTION OF THE ORE MINERALS.

General statement.—The ore minerals of the Virgilina district, named in the approximate order of their abundance, are: Bornite, chalcocite, malachite, native copper, azurite, cuprite, chalcopyrite, chrysocolla, klaprothite, pyrite, argentite, silver, and gold. It should be stated that this enumeration of the minerals is applicable to the copper and not to the gold deposits. In the gold deposits there is very little copper and the principal mineral is native gold, which occurs in the more or less silicified schist.

The following minerals are regarded as of hypogene or primary deposition: Bornite (in part), chalcocite (in part), native copper (in the deposits of the Catoctin type), chalcopyrite (in part), klaprothite, pyrite, argentite, and gold. The following minerals are regarded as of supergene or secondary deposition: chalcocite (in part), native copper (in all except the deposits of the Catoctin type), chalcopyrite (in part), bornite (in part), malachite, azurite, cuprite, chrysocolla, and native silver.

It might be well to add a word of explanation as to the use of the terms hypogene and supergene in describing the ores. These terms are not exact synonyms of the terms primary and secondary, respectively. Hypogene is used to designate the mineralization brought about through deep-seated agencies, solutions or otherwise. Supergene is used to designate the alterations and mineralization which have been brought about through superficial agencies, meteoric waters, oxygen, etc. It is, therefore, clear that they are

not used synonymously with the words primary and secondary as applied to the deposition of ores. A mineral may, therefore, be secondary in a mineralogical sense and still be of hypogene origin. In fact, some students of the Virgilina ores believe that the chalcocite which occurs in graphic intergrowth with the bornite is, in a mineralogical sense, secondary to the bornite, but still of hypogene origin. That is, they believe that this chalcocite was formed later than the bornite, but by deep-seated agencies. Such observers believe that the chalcocite which fills fractures in the bornite is also secondary in a mineralogical sense and at the same time of supergene origin. That is, they believe this chalcocite is younger than the bornite, that it was formed by descending meteoric water, and that it was probably derived from the bornite.

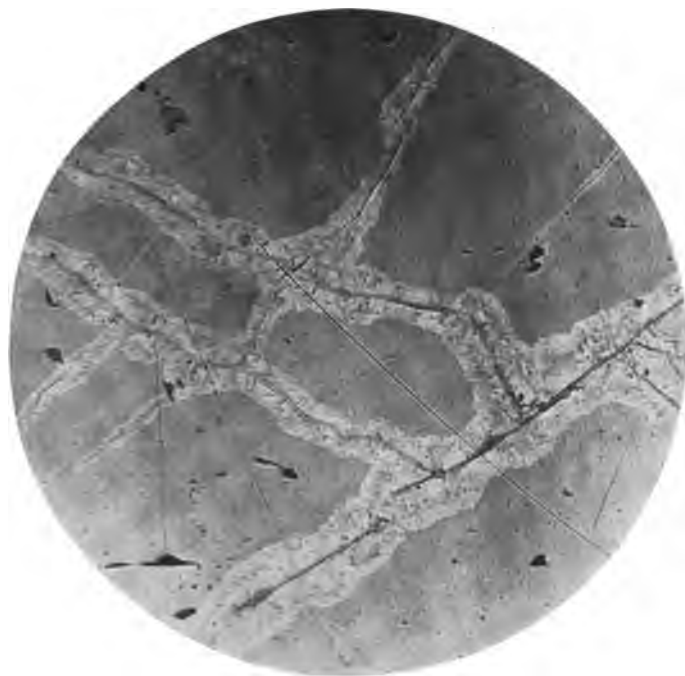
Bornite.—Bornite (peacock copper, Cu_5FeS_4 , 63.33 per cent copper, 25.55 per cent sulphur, and 11.12 per cent iron) is the most abundant of the hypogene minerals of the district. It occurs in all the ore deposits and forms the most important of the so-called primary minerals. It is always massive, but often has a recognizable crystalline structure, and is almost invariably more or less intricately intergrown with chalcocite. On a fresh fracture the mineral has a beautiful bronze color, tarnishing readily and quickly to a kind of copper red, which in turn changes after a short time to an indigo blue. The purest bornite found in the district, that is, the bornite with the least chalcocite, occurs in the Seaboard mine. In most occurrences it is so intimately intergrown with chalcocite that it is all but impossible to free the two. When a polished section of bornite is etched and examined with the microscope it is seen to be made up of an interlocking mass of medium-sized, anhedral grains of different orientation. When the mineral is intergrown with chalcocite the intergrowths, when they involve the individual grains, are invariably along definite crystallographic directions of the two minerals.

In a recent article^a Allen has shown that the chemical composition of natural bornite is Cu_5FeS_4 instead of Cu_3FeS_3 , as given in most text-books of mineralogy. In this paper he quotes an analysis of bornite from the Virgilina district by Dr. Chase Palmer^b of the U. S. Geological Survey as follows:

	<i>Per cent</i>
Cu	62.50
Fe	11.64
S	25.40

^a Allen, E. T.: The composition of natural bornite, *Am. Jour. Sci.*, 1916, Vol. 41, pp. 409-413.

^b *Jour. Washington Acad. Sci.*, 1915, Vol. 5, p. 351.



5mm

- (B) Photomicrograph of a polished section of ore from the Seaboard mine. Shows typical development of supergene (secondary) chalcocite in bornite. Similar in all respects to (A), except that the alteration in this section is farther advanced, and the statements made in regard to (A) are equally applicable to this section. It may be noted that there are at least two constituents in the chalcocite areas. These, so far as could be determined, consist of quartz and limonite. They are better shown in Plate XIII (A) and (B), which is a more highly magnified area from a polished section of ore from the Seaboard mine which shows the same phenomena in better development.

Light gray = chalcocite. Dark gray = bornite. Black = pits.



5mm

- (A) Photomicrograph of a polished section of ore from the Seaboard mine. Shows typical development of supergene (secondary) chalcocite in fractures in bornite. The alteration begins in the minute fracture-openings, often so small that they are invisible except with the very highest powers of the microscope, and extends inward into the bornite until in the end only minute island-like patches of bornite remain in a mass of chalcocite. In many instances, as shown in the largest fracture in the photomicrograph, a line of quartz and iron oxide marks the original fracture in which the chalcocite began to develop.

This pattern is very different from the graphic intergrowth, and is strong evidence against the supergene origin of such intergrowths.

White lines = chalcocite. Dark areas = bornite.

This analysis which differs very slightly from the theoretical composition of the mineral shows the exceptional purity of some of the Virgilina bornite. The only impurity recognized by Dr. Palmer in the specimen analyzed was a minute amount of chalcopyrite.

Like chalcocite and chalcopyrite, the bornite of the Virgilina district is of two periods of deposition. One portion, by far the largest, is of hypogene origin and constitutes the most important original or primary ore mineral of the district. Another portion, much smaller than the first, is of supergene origin and occurs as a replacement mineral in veinlets in chalcopyrite. Except in the ore from the Glasscock shaft of the Pontiac mine and in that from the Cornfield No. 2 prospect, bornite is very rarely found in association with chalcopyrite. It was in specimens of ore from the Cornfield No. 2 prospect that the supergene replacements of chalcopyrite by bornite were found. This subject is treated in considerable detail on page 153, and the descriptions need not be repeated in this place. Plates IX and X are photomicrographs of ore showing bornite in its different relations to chalcopyrite.

Occasionally, as a result of supergene processes, bornite alters to chalcopyrite, as is shown in Plate IX (A). The alteration is discussed in detail on page 87. The usual and most frequent alteration of bornite in the Virgilina district is to chalcocite, and unless the chalcocite which occurs in graphic intergrowth with the bornite represents a hypogene alteration of the bornite, which the writer thinks is not the case, the chalcocitization of the bornite in this district is always a supergene alteration and is brought about only by superficial agencies. A typical intergrowth of bornite and chalcocite is shown in Plate XV (A and B). There is nothing in connection with such intergrowths, so far as the writer can see, that even suggests a replacement of the bornite by chalcocite. Such, however, is not the case as regards the chalcocite which occurs in fractures in the bornite as shown in Plate VIII (A and B). This type of ore is characteristic of the upper portion of the deposits, and so far as the observations of the writer have extended is not found below the depths reached by superficial alterations. It is clearly of supergene origin, represents secondary enrichment, and is brought about by descending meteoric waters. The relation of bornite and chalcocite to each other is discussed in detail in another place, page 83, and need not be repeated here.

Chalcocite.—Chalcocite (copper glance or vitreous copper, Cu_2S , 79.80 per cent copper and 20.20 per cent sulphur) as an ore mineral in the

Virgilina district is second in importance only to bornite, and the two together make up probably 90 per cent of all the copper-bearing minerals of the district. Indeed, it is doubtful that chalcocite is even subordinate to bornite. In the Holloway mine, so far as could be determined, chalcocite was by far the more abundant of the two minerals, but, as regards the other mines, it is probably subordinate to bornite. So far as observations have extended chalcocite occurs in the district only in the massive form. A careful lookout for chalcocite crystals was kept during the entire field work, but none was found. As is well shown under the microscope, the massive mineral as it occurs in this district is made up of irregular, interlocking, small-to medium-sized anhedral grains of different orientation. So far as could be determined from the cleavage in the different grains, as brought out by etching a polished surface, the mineral is in the orthorhombic form. Some students of the Virgilina ore deposits take this fact as proof that the chalcocite was deposited from low temperature solutions. It has been shown by Allen* that artificial chalcocite, when deposited at a temperature above 91 degrees C., crystallizes in the isometric system, and when at lower temperature it assumes the orthorhombic form. It is not known that the same is true of chalcocite deposited under the conditions of temperature and pressure that prevail during the deposition of minerals in the deep-vein zone. Under such conditions it is not known that chalcocite could not be deposited in the orthorhombic form at a much higher temperature than 91 degrees C., or, even if it were deposited in the isometric form, it is not known that it might not, in the course of time, or as a result of changes in the conditions, revert to the orthorhombic form. Until more is known about the subject the writer feels that it is not safe to base any far-reaching conclusions as to the origin of natural chalcocite or the temperature at which it was deposited, on so slender a premise as the relation of temperature to the crystal form of artificial chalcocite. He believes that the relation of chalcocite and bornite to each other, as well as the general conditions of the vein, indicate very strongly that the graphically intergrown bornite and chalcocite were deposited contemporaneously and that they are, therefore, both deep-seated hypogene minerals.

Chalcocite occurs in two very distinct ways in the bornite: as a supergene mineral secondary to and filling fractures in the bornite, and as a hypogene mineral intergrown, in many instances graphically, with it. The former type is shown in Plate XIV and in Plate XVI (A and B). The

* Posnjak, E., Allen, E. T., and Merwin, H. E.: *Economic Geology*, Vol. 10, 1915, p. 491.

latter type is well illustrated in Plates VIII and XII. The supergene or secondary chalcocite occurs for the most part in two forms, as replacement of the bornite along lines of fracture, and as rims of varying width representing replacement that has taken place around the periphery of areas of quartz embedded in the bornite and at the contact between bornite and larger areas of quartz. These types of replacement are also characteristic of chalcocite in chalcopyrite. They are illustrated in Plates IX and XI. In one instance, in ore from the Cornfield No. 2 prospect, a specimen was found which showed a rim of chalcopyrite between an area of quartz and bornite with a minute rim of chalcocite between the chalcopyrite and the quartz. This specimen is illustrated in Plate IX (A). These relations between the different minerals indicate that the bornite was first replaced by the chalcopyrite which in turn was replaced by chalcocite. In all the clearly supergene or secondary chalcocite examined, regardless of the mineral or minerals with which it was associated and from which it had been derived, it was invariably closely related with fractures in the original sulphide or to a contact between the original sulphide and a gangue mineral, usually quartz. Such, however, is certainly not the case with the chalcocite which is intergrown with the bornite. It is true that there are many fractures across the intergrown sulphides, in which chalcocite has developed, but they are clearly later than the intergrowths, and, so far as the writer was able to ascertain, had absolutely nothing to do with their development.

The color of the hypogene chalcocite is by no means uniform, but presents various tints of bluish-gray. Occasionally a specimen is found which in polished section shows areas of the mineral of different colors, each clearly outlined from the others and having its own distinct figure or pattern. This fact has been noted in chalcocite from other localities, especially from Butte, Mont., but the causes underlying its formation are not known. Chalcocite of two colors is shown in Plate XIX (A). In this instance the areas of the mineral having the deeper color are graphically intergrown with bornite while the others are not.

Chalcopyrite.—Chalcopyrite (yellow copper, $\text{Cu}_2\text{S} \cdot \text{Fe}_2\text{S}_3$, copper 34.50 per cent, and sulphur, 35.00 per cent) is found in sufficient quantity to be of any importance as an ore in only two mines or prospects in the Virgilina district, the Pontiac and the Cornfield No. 2 prospects. In all other mines or prospects, so far as could be determined, the mineral, if present at all, occurs only in very small amount. In fact, except in the two places just mentioned, chalcopyrite is one of the scarcest minerals in the district. It

occurs in two ways in both of these prospects, as a hypogene mineral, contemporaneous with the bornite with which it is more or less intricately intergrown, and as a supergene mineral filling fractures in the bornite and as rims around quartz areas embedded within the bornite. Plate IX (A and B) shows the supergene, while Plate X (A) shows the hypogene chalcopyrite. In many instances the associations of hypogene chalcopyrite and bornite are apparently similar in all respects, as regards physical form and pattern, to those of hypogene bornite and hypogene chalcocite as illustrated in Plate XIV (A and B). An interesting relation between bornite and chalcopyrite is shown in Plate X (A). In this instance the bornite appears to be secondary to and to have replaced the chalcopyrite, but whether it is of hypogene or supergene origin is not clear. It appears to have developed in a fracture in the chalcopyrite, and extending outward from the fracture to have extended to varying distances into the host mineral. Following the change, after considerable secondary bornite had developed, the conditions evidently changed and some of the bornite was altered to chalcopyrite, which occurs as minute veinlets in the bornite. A still later change in the conditions is shown by the fact that some of the secondary bornite as well as some of the secondary chalcopyrite has been altered into chalcocite. These last two alterations are pretty clearly of supergene origin; the first alteration in the series, that of the chalcopyrite, is believed to be of supergene origin. However, if, as some students believe, the intergrown chalcocite represents a hypogene alteration of bornite, it appears to the writer that the alteration of chalcopyrite into bornite, as it occurs in the ores from Cornfield No. 2 prospect, may possibly be of hypogene origin.

Native copper.—Native copper occurs in the Virgilina district in two ways: as a supergene mineral in the upper zones of the sulphide-bearing veins, and as a hypogene mineral closely associated with quartz and epidote in the so-called native copper deposits; that is, in deposits of the Catoctin type, such as the Native Shaft in the southern limits of the town of Virgilina, and in the Pannebaker and other prospects farther south in the same area.

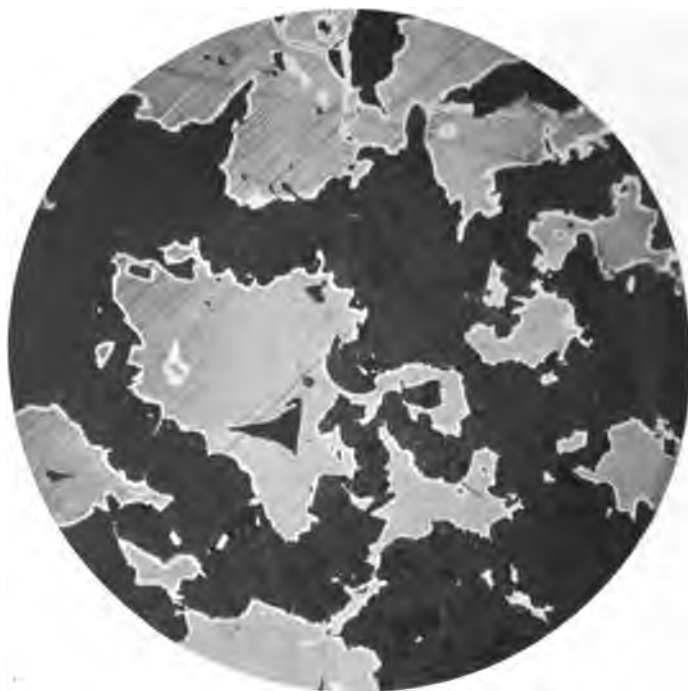
Native copper of the first type, so far as observations have extended, occurs almost invariably as thin plates in fractures in the altered ores, and is confined to the upper and altered portions of the veins. It was found in the High Hill, the Holloway, and the Durgy mines, and it probably occurred in other openings. It is present only in minute quantities and consequently is of no importance commercially.



5mm

- (A) Photomicrograph of a polished section of ore from Cornfield Prospect No. 1. Shows supergene chalcopyrite occurring as a rim at the contact of bornite and quartz and as gash veinlets in the bornite. Supergene chalcocite also occurs as a very narrow rim at the contact of the quartz and chalcopyrite, indicating that after the replacement of the bornite by chalcopyrite at the quartz contact, conditions changed and the chalcopyrite was replaced by chalcocite at the contact of the chalcopyrite. The photograph does not distinguish between the chalcopyrite and the chalcocite.

White lines and rim = chalcopyrite. Gray = bornite. Larger black area = quartz. Black dots = pits.



.5 mm

- (B) Photomicrograph of a polished section of ore from Cornfield Prospect No. 1. Shows supergene chalcocite occurring as rims around irregular areas of bornite.

White = chalcocite. Gray = bornite. Black = quartz.



.5mm

- (B) Photomicrograph of a polished section of ore from Cornfield Prospect No. 1. Shows bornite in what are believed to be both supergene and hypogene relations with hypogene chalcopyrite, together with gash veinlets of supergene chalcopyrite in the supergene bornite. Supergene bornite that could be recognized as such is very rare in the Virgilina district; in fact, it was found only in this one prospect. In this section it occurs in what appears to have been a fracture in the hypogene chalcopyrite and to have developed from it in a manner similar to that of the formation of chalcocite in fractures in bornite. Minute veins of supergene chalcopyrite and chalcocite are seen in the large area of supergene bornite.

Light gray = chalcopyrite. Dark gray = bornite. Light gray
veinlets = chalcopyrite. Darker gray veinlets = chalcocite.
Black = quartz.



.5 mm

- (A) Photomicrograph of a polished section of ore from Cornfield Prospect No. 1. Shows bornite and chalcopyrite in typical association in ore which is believed to be of hypogene origin. The pattern formed by the intergrowth very closely resembles the coarser intergrowths of bornite and chalcocite, but there are not so many hook-shaped forms. Occurring as rims at the contact of both chalcopyrite and bornite and quartz, and as narrow gash veinlets in both, is a small amount of supergene chalcocite.

White areas = chalcopyrite. Dark gray areas = bornite. Light gray rims and veinlets = chalcocite. Black = quartz.

The native copper in the deposits of the Catoclin type does not occur in veins, but in silicified and epidotized areas of the Virgilina greenstone. These deposits are always of irregular outline and the metal is distributed very irregularly through the quartz and epidote, evidently preferring the quartz, but occasionally in the epidote. Weed^a believes that as a general rule copper deposits of the Catoclin type are formed by superficial alteration and that the values are always of shallow depth. So far as the writer's observations have extended, the native copper deposits of the Virgilina district are clearly of hypogene origin, and he believes there are no valid reasons for assuming that they are limited to shallow depth.

In these deposits the copper occurs in irregular and distorted crystals, as in irregular branching or tree-like form which generally show imperfect crystal faces, and as anhedral grains which seem to have accommodated themselves to the spaces available for their development. The copper as a rule is fairly pure, but in some instances it contains an appreciable amount of silver.

Klaprothite or Klaprotholite.—Klaprothite, $3\text{Cu}_2\text{S} \cdot 2\text{Bi}_2\text{S}_3$ (copper 25.30 per cent, bismuth 55.53 per cent, sulphur 19.17 per cent), a copper-bismuth sulphide, or at least a mineral having the physical properties of klaprothite, so far as they could be determined under the microscope, occurs very sparingly in the Virgilina ores. Thus far it has been found only in microscopic grains which could not be isolated for chemical examination. It was carefully compared under the microscope with known klaprothite from Butte, Mont., and so far as could be determined the two minerals are identical. The mineral was found only as small grains of fairly regular outline, embedded in the bornite.

Pyrite.—Pyrite (iron pyrites, "fool's gold," FeS_2) is one of the scarcest minerals in the Virgilina rocks and ores. In fact, it is so rare that one, unless he exercises the greatest care, will overlook it entirely. It was found most plentifully in the Cornfield No. 2 prospect, and in very small amount in ore from the Durgy and Blue Wing mines. It occurs as minute crystals and in veinlets in the greenstone associated with the ores.

The statements just made apply to the copper and not to the gold mines and prospects, in which pyrite while by no means an abundant mineral is present in appreciable amount.

Argentite.—Argentite (vitreous silver, silver glance, Ag_2S , silver 87.10 per cent, sulphur 12.90 per cent) is distributed throughout the bornite and

^a. Weed, Walter H.: Types of copper deposits in the Southern United States. Trans. Am. Inst. Min. Eng., Vol. 30, 1900, pp. 498-499.

chalcocite in minute amounts. Indeed it is so rare that the most careful microscopic examination of a great many polished sections of the richest ores at high magnification will be necessary in order to locate it. It was found in ore from the Blue Wing and the Durgy mines, respectively, in which it occurs as minute grains of fairly regular outline. So far as the writer could determine argentite does not replace the minerals in which it occurs, and it is believed to be of hypogene origin and contemporaneous with the sulphides in which it occurs. Such evidence as could be obtained indicates very strongly that all the silver in the original ores occurs in the form of argentite. The silver value, while it increases with the copper value of the ores and concentrates, varies widely in different samples from the same mine, and by no means bears a regular ratio to the copper as it necessarily should if silver were in chemical combination with either of the copper-bearing sulphides. In the reports of assays from the Durgy mine, available to the writer for study, the silver values varied from a trace to nearly one-half ounce per ton for each per cent of copper in the ore. This is a wider variation than might reasonably be expected if the silver were in chemical union with the copper-bearing sulphides, and exactly what would result if the silver were present as a definite silver mineral and irregularly distributed throughout the copper-bearing sulphides.

Gold.—Gold occurs in varying quantity in the ores from all the mines in the district, the amount varying from a trace to about 0.13 ounce to one per cent of copper. The gold values, however, are very irregular, and so far as can be estimated from such data as were available the average gold value is probably not much more than one-tenth of this amount.

Of the accessible records those from the Durgy mine showed the highest gold values. However, so far as could be learned, there is very little difference in the gold value of the ore from the different mines.

So far as is known the gold in the copper-bearing sulphides occurs only as the native metal. The assay records all show great variation in the gold value and that there is little or no ratio between it and the percentage of copper, facts which show that the gold is not a regular constituent of the copper-bearing minerals.

A careful lookout was kept during all the field work for specimens of copper ores carrying gold in visible quantity, but without success. The search was continued with the microscope in the laboratory with only doubtful results. The operators in the district state that occasionally a



.5mm

- (A) Photomicrograph of a polished section of ore from Cornfield Prospect No. 1. Shows hypogene bornite and chalcopyrite and supergene chalcocite in quartz. The chalcopyrite is included in the bornite, while the chalcocite forms a narrow rim around the irregular areas of the bornite and chalcopyrite. White in the gray = chalcopyrite. Gray = bornite. Light rims = chalcocite. Black = quartz.



.5 m m

- (B) Photomicrograph of a polished section of ore from Cornfield Prospect No. 1, showing supergene (secondary) chalcocite in bornite. The chalcocite in this section, while it is pretty clearly of supergene origin, shows almost typical graphic intergrowths between the two sulphides, thus affording strong evidence that such intergrowths may result from supergene agencies and that taken alone they are not of very great diagnostic value in deciding questions as to origin of chalcocite.

White = chalcocite. Gray = bornite. Black = pits.
Intersecting lines = scratches from polishing.

specimen is found in which the gold can readily be seen. Pratt^a in his professional report on the Durgy mine confirms these statements. He says:

"In cleaning up the Chilian mill, after crushing a considerable amount of ore, there are often found small nuggets of free gold, some of which have weighed from 8 to 10 dw't."

Malachite.—Malachite (the green carbonate of copper, $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$, cupric oxide 71.90 per cent, carbon dioxide 19.90 per cent, water 8.20 per cent), the basic, green carbonate of copper, occurs prominently as a coating and stain in the oxidized portions of all the copper deposits in the district. In most instances it consists of only thin films and stains in the quartz, and other vein matter, and in the greenstone lying next to the copper minerals, and of itself is of little or no commercial value. In a few cases, as at the Glasscock shaft of the Pontiac mine and in the upper part of the Holloway mine, it occurred in larger amount, in radiating tufts and masses, and was probably valuable as an ore. It is clearly of supergene origin and is formed by the oxidation of the copper-bearing minerals and native copper. Malachite forms the principal criterion for guiding the prospector in his search for copper deposits in the district.

Azurite.—Azurite (the blue carbonate of copper, $2\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$, cupric oxide 62.20 per cent, carbon dioxide 25.60 per cent, water 5.20 per cent), the basic, blue carbonate of copper, is found with malachite in the oxidized ores from all mines and prospects in the district, but in much smaller amount than the green carbonate. In a few places, especially in the Glasscock shaft of the Pontiac mine and in a few places in the Holloway mine, it was more abundant. In the Glasscock ore it occasionally is found in well-formed monoclinic crystals. In this mine azurite was found in sufficient quantity to have some value as an ore. It must be stated, however, that in this district the copper carbonates are present in such small amount that they are of little or no importance commercially.

Cuprite.—Cuprite (red oxide of copper, Cu_2O , copper 88.80 per cent, oxygen 12.20 per cent), while present only in small amount, occurs in the oxidized portions of practically all the mines and prospects in the district. It is more abundant in the so-called "native deposits," that is, deposits of the Catoctin type, than in the vein deposits. In these deposits it usually is found as a red stain in the associated rock or coating and replacing the particles of native copper. It is usually massive, but occa-

^a Pratt, Joseph Hyde: A Report on the Property of the Person Consolidated Copper and Gold Mines Company. 1904, p. 6.

sionally is found showing more or less well-developed crystal faces, and very rarely in the form of long, acicular, hair-like filaments, the so-called "plush copper ore," or chalcotrichite. In this last-mentioned form the mineral was found only in the Copper King mine in which, in very rare instances, it occurs in small vugs in the partially oxidized ore. Except in the "native deposits" cuprite is negligible as an ore of copper.

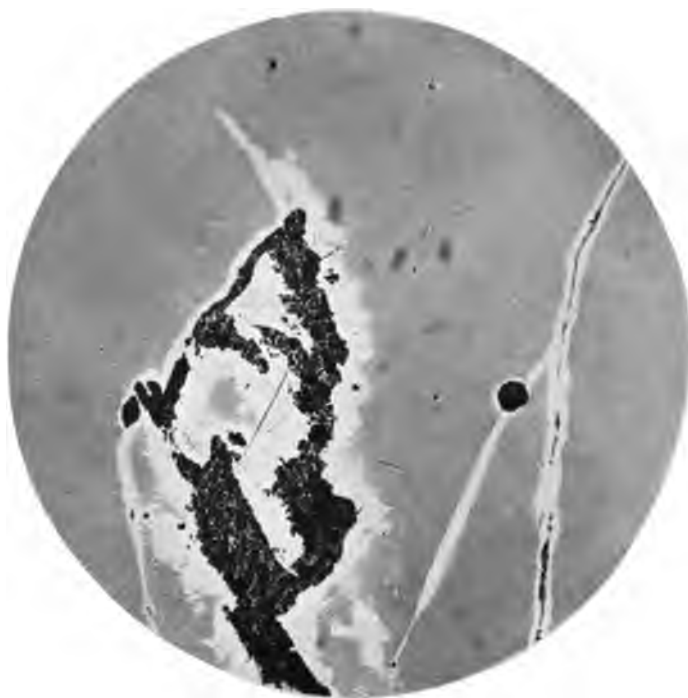
Melaconite.—Some of the black, earthy material closely associated with the partially altered material on the old dump at the Gillis mine closely resembles melaconite, the impure cupric oxide. Very little of the material was available, and the writer was not able to positively identify it. However, it is believed to be melaconite. It is clearly an alteration product from the usual copper ores and in this district is of no importance as an ore.

Chrysocolla.—The Gillis mine has also the distinction of having furnished the only chrysocolla, the hydrous silicate of copper, found in the district. The material was found in a small pile of ore which had lain upon the dump for years. The color varied from greenish-blue to dark brown and the mineral was evidently very impure. Physical and chemical tests, however, made the identification reasonably certain. The mineral is present in only small amount and is of no importance as an ore.

Native silver.—Native silver has been reported as occurring in minute amount in the upper portion of the sulphides in nearly all of the important mines of the district. The writer was able to find the mineral only in a single piece of ore from the dump of the High Hill mine. In this specimen the silver occurred as a thin film in a minute fracture in the ore, and was clearly of supergene origin.

RELATION OF THE COPPER-BEARING SULPHIDES TO EACH OTHER.

General statement.—The relations of the sulphides to each other have been discussed with some thoroughness in the pages devoted to the detailed description of the ores, pp. 63-82, but it has been thought best to repeat and to some extent enlarge, in this place, the descriptions of the interrelations of the ore minerals which have a bearing upon their origin, deposition, and the secondary alterations which they have suffered. Of greatest importance in these respects are the graphic intergrowths between bornite and chalcocite in the primary ores, or, in other words, the ores believed to be of hypogene origin. These relationships are so characteristically different from those of the secondary, or supergene sulphides,



.5 mm

- (B) Photomicrograph of a polished section of ore from the Pontiac mine (Glasscock shaft). Shows typical supergene chalcocite in bornite. Similar in all respects to the section shown in (A).

White = chalcocite. Gray = bornite. Black = pits.



_____ .5 mm _____

- (A) Photomicrograph of a polished section of ore from Cornfield Prospect No. 2. Shows very clearly the typical pattern of supergene chalcocite in bornite. Note the irregularity of outline and the ragged edges of the chalcocite. It is a far cry from this sort of pattern to the regularity of pattern and even line boundaries between the two sulphides in the graphic intergrowths such as are shown in plates XVI and XVIII. It does not seem possible that similar agencies acting under similar conditions and upon exactly similar minerals could produce results so markedly different.

Light gray = chalcocite. Dark gray = bornite. Black = pits.

that when the two are contrasted it is very difficult to understand how the two types or textures could have been formed by similar processes. These features will be discussed and illustrated, and some surmises as to the origin of the different textures will be made, and their bearing upon the broader subject, the origin and deposition of the ores, will be considered.

Relations of bornite and chalcocite.—In the ores of the Virgilina district bornite and chalcocite occur in two very distinct relations to each other. In the first type the chalcocite occurs in the bornite in well-defined graphic intergrowths which so far as form is concerned are similar to the eutectic intergrowths in alloys, and there appears to be no conclusive evidence that the two sulphides are not of contemporaneous deposition. In the second type the chalcocite occurs in fractures, in irregular areas, and as rims around areas of bornite. The relations of the two sulphides in this case make it perfectly clear that the chalcocite is of supergene origin and that it has replaced the bornite.

The intergrowths between bornite and chalcocite occur in two forms, one in which the two minerals show a more or less irregular distribution, and one typically graphic.

The irregular intergrowth, as it is seen under the reflecting microscope, consists of myriads of the most irregular, angular, and hook-shaped areas of chalcocite embedded within the bornite. The appearance can best be imagined by thinking of a section through a honeycombed, cellular, or sponge-like mass of chalcocite so completely merged into a similar mass of bornite as to leave absolutely no spaces between the two components. So far as could be determined from careful microscopic study of more than 100 polished sections of such intergrowths, the chalcocite is in no way related to fractures in the bornite nor to any known process of supergene alteration. Many specimens examined contained fractures in which supergene chalcocite had formed, but these, so far as the writer could determine, cut across both minerals of the intergrowths alike without showing any indication that the intergrown chalcocite was genetically related to the fractures in any way. Many specimens of such intergrowths were to a greater or less extent porous, so that when polished sections were made the surfaces presented minute pits and openings. These, while apparently more numerous in the bornite, were by no means confined to it, and none of them were found which showed any alteration of the bornite around the openings, except where a fracture had broken through the opening. This type of intergrowth is found in great abundance in the ores from all the

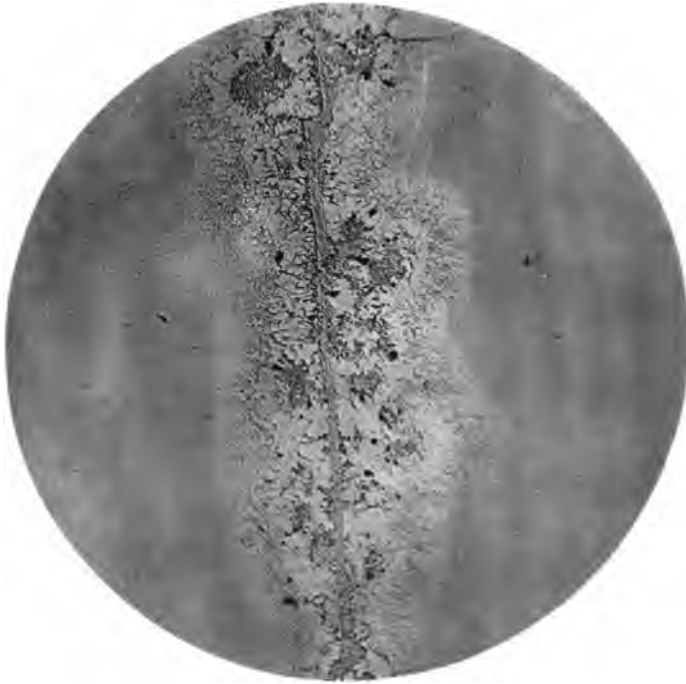
mines. In fact it is characteristic of the Virgilina ores, and, so far as observations have extended, it is not in any way related to the depth from which the ores are taken. Fine examples were found in ores from the deepest workings of the High Hill, the Seaboard, the Blue Wing, and the Durgy mines.

In many instances a single area under the microscope shows a field in which the irregular and the graphic intergrowths both occur, Plate XVII (A). In fact, it appears that the graphic is only a special case of the irregular intergrowth in which the form of the intergrowth was controlled by the crystallographic phenomena of the two minerals. Photomicrographs of typical irregular intergrowths are shown in Plate XIV (A and B).

In the polished section the typically graphic intergrowths occur in three fairly well-defined types, one in which the two minerals occur in more or less regular, alternating lamellæ, one which presents a reticulated pattern, and a third which is more or less irregular. It is not intended to state that these three types of graphic intergrowth are separate and distinct from each other, for there is every gradation from one into the other. In fact almost any graphic intergrowth will present an example or examples of all three types.

In the graphic lamellar intergrowth the bornite and chalcocite occur in minute alternating lamellæ, with still more minute lines of one mineral, usually chalcocite, breaking across a band of the other and joining another of its own kind. The pattern of this type of intergrowth when seen in polished section is an almost exact duplicate of the pearlite eutectoid in steel. Pearlite consists of a mechanical mixture of ferrite (free alpha iron) and cementite (an iron carbide, Fe_3C). Pearlite results from the contemporaneous solidification of ferrite and cementite as the alloy cools. Thus the lamellar graphic intergrowths still more closely resemble the eutectic or eutectoid structures of alloys. So far as observations have extended the lamellar intergrowths of these ores bear no relationship to fractures in the bornite and probably not to any known supergene processes. Such intergrowths are illustrated in Plate XVIII (A and B), and in Plate XVI (B). When these lamellar intergrowths are etched so as to reveal the internal structure of the component minerals, it is clearly seen that the intergrowths have developed along crystallographic directions in the minerals, and that, regardless of the method of their development, they are really crystallographic intergrowths.

The irregular graphic intergrowths differ from those of the lamellar pattern only in that the anastomosing filaments or branches of the com-

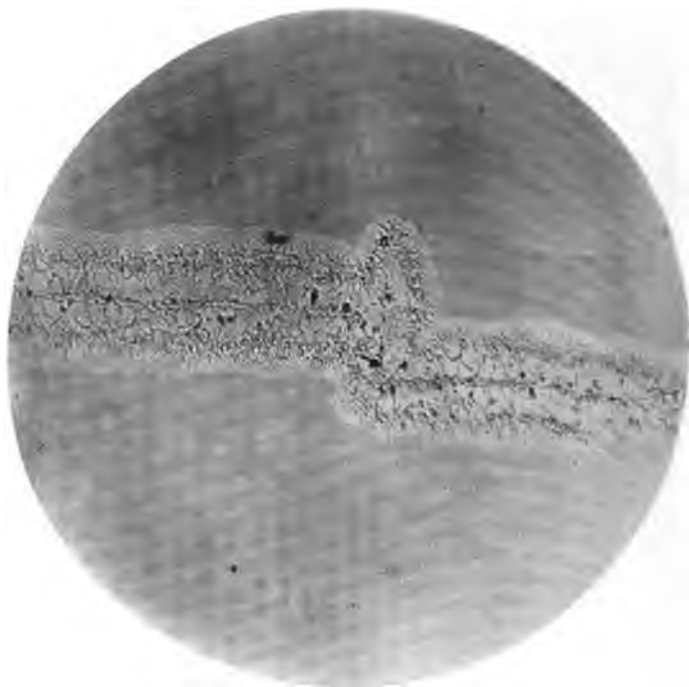


2mm

- (A) Photomicrograph of a polished section of ore from the Seaboard mine. Shows the network of quartz and iron oxide that occasionally occurs in chalcocite veinlets which develop in fractures in bornite. In this structure the chalcocite at the borders of the developing veinlets is fairly pure. The anastomosing network of minute threads of quartz and limonite follow the replacement process very closely and extends its filaments, in many instances almost to the outer edge of the chalcocite.

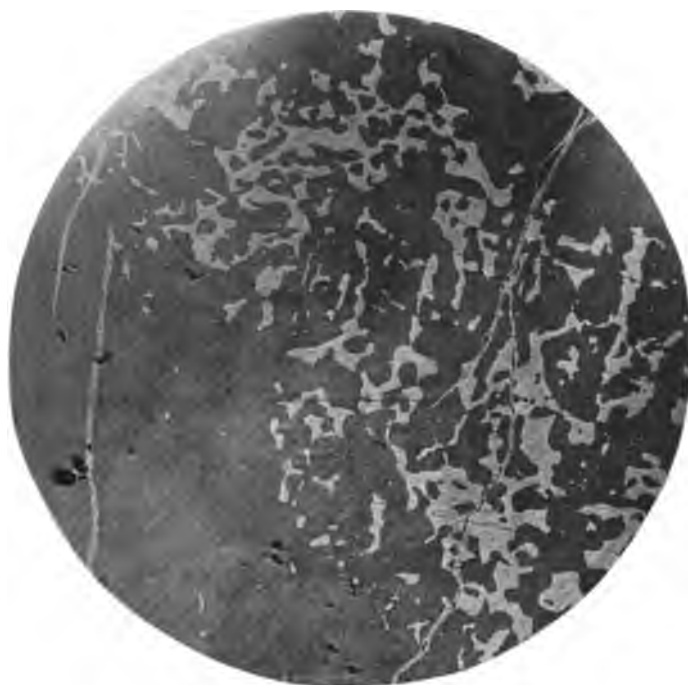
These are strange phenomena and the writer can not offer an explanation as to their origin and development.

Light gray = chalcocite. Dark gray = bornite.
Network in light gray = limonite and quartz.



2 mm

- (B) Photomicrograph of a different area in the polished section illustrated in (A). Similar in all respects to (A), except that it shows a kind of banding of the limonite and quartz on each side of the center of the veinlet of chalcocite. The notes on (A) are equally applicable to this section.



5mm

- (B) Photomicrograph of a polished section of ore from the Durgy mine. Shows chalcocite of two periods of deposition, one of hypogene origin intergrown normally with the bornite, and one of supergene origin and filling fractures which cross both the hypogene chalcocite and the bornite. So far as could be determined the fracturing occurred long since the intergrown chalcocite was deposited and is in no way related to it.

White = chalcocite. Dark = bornite. Black = pits.



5 mm

- (A) Photomicrograph of a polished section of ore from the Blue Wing mine. Shows normal intergrowth of hypogene chalcocite and bornite. So far as can be determined the areas of chalcocite are in no way related to fractures in the bornite nor to any visible channels of circulation along which solutions could flow. In fact the ore is perfectly massive and the texture here illustrated extends throughout all the ore of the deposit. If it represents secondary enrichment by supergene processes it remains to explain the means by which the solutions penetrated every portion of the massive bornite. Until proof to the contrary has been produced the writer will adhere to the belief that such intergrowths are the result of hypogene processes and that the two sulphides are of contemporaneous deposition.

White = chalcocite. Dark = bornite.

ponent minerals, instead of lying in roughly parallel lamellæ, bear a most intricate relation to each other. In most instances they appear to make up larger areas of the ore and the filaments are slightly larger than those of the lamellar intergrowths. They also are of more frequent occurrence. This type of intergrowth also, so far as physical form is concerned, very strikingly resembles certain copper-silver alloys, and many copper-rich mattes. The resemblance is so close that if unmarked photomicrographs of the three—the ore, the alloy, and the matte—are placed side by side, it is exceedingly difficult if not impossible to distinguish one type of structure from the other. Such graphic intergrowths are shown by etching to have formed along definite crystallographic directions, such as cleavage or parting planes in the minerals involved. They are therefore crystallographic as well as graphic. Photomicrographs of typical examples of this type of intergrowth are shown in Plates XVI and XVII.

The reticulated graphic intergrowths are similar to the irregular type except that in most instances the filaments of the intergrowth are joined so as to form triangles and irregular-shaped closed areas. Etching reveals the fact that those intergrowths in most cases have taken place along crystallographic directions, and that in their formation crystallographic phenomena determined the form of the intergrowth. In the material available for study, reticulated intergrowths were very rare. Unsatisfactory photomicrographs of this type of graphic intergrowth are shown in Plate XX.

As has been said, these intergrowths are in reality all special cases of the irregular intergrowths of bornite and chalcocite which have already been described. So far as the writer's observations have extended these intergrowths do not bear any genetic relation whatsoever to fractures or channels of circulation in the bornite, and so far as could be determined they are in no way connected with any known supergene processes. The pattern formed by the two minerals as seen in polished section bears a striking resemblance to the pattern formed in alloys of two components, one of which is present in excess. In some areas of such an alloy one component will be found in excess, in another area the other component will be in excess, while in still another the two will be present in graphic intergrowth in the form of a eutectic. Of course it is not intended to even suggest that these ores were deposited from so simple a system as one of only two components. It is altogether probable that a great many components entered into the system from which they were precipitated.

In the second great type of the relation of chalcocite to bornite in the Virgilina district the chalcocite occurs as veinlets of varying size in

fractures in the bornite, as rims around small areas of bornite, and as irregular areas surrounding openings in the bornite. This type of chalcocite invariably shows unmistakable signs of supergene origin and forms as a replacement of bornite. Very little beyond the photomicrographs of the different phases is necessary in the way of description of such ores. They show the relation of the two minerals to each other better than can be explained in written descriptions.

The veinlets of supergene chalcocite in bornite vary in width from sub-capillary cracks, scarcely visible even with the highest powers of the microscope, up to well-defined veins 10 or more centimeters in width. Certain specimens from the Cornfield Prospect No. 1 showed fractures in the bornite so small that they were not clearly visible at a magnification of over 2,100 diameters, which were rimmed with films of chalcocite, thus showing that such minute fractures could serve as channels for circulating supergene solutions. The alteration proceeds outward from the fractures until the whole mass of bornite has been changed into chalcocite. It was interesting to note that in every specimen examined the contact between the bornite and chalcocite is invariably perfectly sharp and clear-cut. It was noted, however, that in some instances the bornite nearest to the contact with the chalcocite tarnished more quickly and apparently more easily than that farther away from the contact. The rapidity of the alteration depends among other factors upon the amount of fracturing which the bornite has suffered. In many of the larger veinlets of such chalcocite there are dendritic "skeletons," as it were, of limonite which was probably derived from the iron in the bornite during the process of alteration. Plate VIII and Plate XII (A and B) are photographs showing veins of such supergene chalcocite in various stages of development. Plate XX (A and B) exhibits photographs showing typical dendritic "skeletons" of limonite in supergene chalcocite veins in bornite.

The rims of supergene chalcocite which form at the contact between bornite and the gangue minerals develop in a manner similar in all respects to that in the veinlets described in the last paragraph, and consequently do not call for further description in this place. Plate XI (A) is a photomicrograph showing such rims of chalcocite at the contact between bornite and quartz.

The irregular areas of supergene chalcocite surrounding openings in bornite are shown in Plate XI (B). They are formed in the same way that the other supergene secondary chalcocite is formed and do not require further description.



5 mm

- (A) Photomicrograph of a polished section of ore from the High Hill mine. Shows graphic and usual intergrowths of bornite and chalcocite. These intergrowths are not in any way connected with fractures in the bornite (at least none are visible at a magnification of 2,500 diameters), and the writer believes the two sulphides are of contemporaneous deposition.

Light = chalcocite. Dark = bornite. Black = pits.



5mm

- (B) Photomicrograph of a polished section of ore from the Durgy mine. Shows a typical graphic intergrowth of bornite and chalcocite. It will be noted that this section shows the irregular intergrowth, while that illustrated in (A) is largely of the lamellar type. They both show very marked similarity to the eutectic structures so characteristic of alloys, mattes, and slags, and the writer believes they represent contemporaneous deposition of the two sulphides.

Light = chalcocite. Dark = bornite.



5mm

- (B) Photomicrograph of a polished section of ore from Cornfield Prospect No. 2. Shows a typical lamellar intergrowth of chalcocite and bornite similar to the exceedingly fine lamellar intergrowth shown in Plate XVIII. When such intergrowths are etched it is clearly shown that in most instances the two minerals are intergrown along crystallographic directions.

White = chalcocite. Dark = bornite.



5mm

- (A) Photomicrograph of a polished section of ore from the Wall mine. Shows a typical example of graphic intergrowth of bornite and chalcocite. This structure is so different from that of supergene chalcocite in bornite and so closely resembles the structures which are characteristic of alloys, mattes, and slags, that the writer, while admitting that it may possibly form as a secondary process, still believes that it is formed in a very different manner from the structures shown in plates VII and VIII. He believes that such structures form as a result of hypogene more often than from supergene processes and that in such cases as this the evidence is far more strongly in favor of a hypogene process and of contemporaneous deposition of the two sulphides.

White = chalcocite. Gray = bornite. Black = pits.

In studying the photomicrographs of the supergene secondary chalcocite and comparing them with those of the hypogene intergrowths of the two minerals especial attention should be given to the form or pattern of the two minerals in each type of ore. A glance is sufficient to demonstrate that they are decidedly different. Indeed they are so different that the writer can not understand how they could all have formed as a result of similar processes. It is known that the second type of chalcocite was formed as the result of supergene processes and that it is secondary to and replaces the bornite, and it is not understood how the same processes could possibly produce types of structure so materially different from the graphic intergrowths, which are consequently believed to be of hypogene origin, and contemporaneous with the bornite.

Relations of bornite and chalcopyrite.—Bornite occurs in two distinct relations to chalcopyrite, as a hypogene mineral intergrown with it, and as a supergene mineral replacing chalcopyrite. Chalcopyrite in turn bears exactly similar relations to bornite. It occurs as a hypogene mineral contemporaneous with bornite and intergrown with it, and as a supergene mineral secondary to and replacing bornite. Chalcopyrite is by no means an abundant mineral in the Virgilina district. In fact, it is very rarely found in any of the larger and extensively developed mines. Indeed it is so rare in all the developed mines in the district that from these alone nothing could have been learned as to its relation to the other sulphides. Fortunately, however, it was found in greater abundance in two partially developed mines, the Glasscock shaft of the Pontiac mine, and the Cornfield No. 2 prospect. From these material was obtained which showed the relations described and illustrated in this chapter. The best specimens were obtained from the Cornfield^a Prospect No. 2. Those from the Glasscock shaft, however, are similar in most respects, and furnish supplementary evidence as to the relation of chalcopyrite to the other sulphides.

The intergrowths of chalcopyrite and bornite are in the main similar to the irregular intergrowths of bornite and chalcocite which were described on p. 83. The relations are not so intricate and no graphic intergrowths of the two sulphides were found. In the intergrowths examined there was

^a This prospect was filled with water while the writer was engaged upon the field work for this report, and therefore not accessible. In the summer of 1915 the owner of the property, Miss Florence Pannebaker, had the shaft unwatered and instituted further development work. Noting the abundance of chalcopyrite, Miss Pannebaker collected and sent to the writer the specimens which are herein described. The writer wishes to acknowledge his obligations to Miss Pannebaker for supplying him with these important specimens and data concerning them.

found absolutely no conclusive evidence, and, indeed, no indications, for that matter, that the chalcopyrite and bornite are not of contemporaneous deposition. It is therefore believed that such is the case and that both sulphides in such instances are of hypogene origin. The photomicrograph, Plate X (A), shows the relationship of the two minerals so well that no further description is necessary.

The supergene bornite, secondary to and replacing chalcopyrite, occurs as veinlets in chalcopyrite probably in the same manner as supergene chalcocite develops in bornite. The photomicrograph, Plate X (B), shows the typical form of occurrence of supergene bornite. It appears to the writer that the evidence that the bornite is of supergene origin and that it has replaced the chalcopyrite along the fractures is perfectly clear.

It was interesting to note that in some areas of the specimen, which showed to best advantage supergene bornite in hypogene chalcopyrite, there was an appreciable amount of supergene chalcopyrite occurring as a replacement of both hypogene and supergene bornite. This supergene and secondary chalcopyrite is by no means abundant, but is found occasionally in ore from both the Cornfield Prospect No. 2 and the Glasscock shaft. It, so far as observations have extended, occurs only in two forms, as veinlets in minute fractures in the bornite, and as rims surrounding particles of bornite at their contact with the different gangue minerals. Plate X (B) shows supergene chalcopyrite occurring as minute veinlets replacing supergene bornite which in turn occurs in the same manner as a replacement of hypogene chalcopyrite. Plate IX (A) is a photomicrograph showing replacement rim of supergene chalcopyrite at the contact of hypogene bornite and a small area of quartz. It is not brought out in the photograph, but the specimen shows that a narrow replacement rim of chalcocite has formed at the contact of the rim of chalcopyrite.

These "flarebacks" or reversals in the normal processes of replacement are not uncommon and are found in many of the well-known copper deposits of the world. They are of common occurrence in the Butte ores. The alteration has also been produced in the laboratory. The method of producing it was discovered by Prof. S. W. Young, of Stanford University, and consists in immersing fragments of chalcocite or bornite in a fairly dilute solution of ferrous sulphate and slowly passing hydrogen sulphide through the solution. The reaction takes place rather quickly and in a short time the fragments will be coated with a film of chalcopyrite. The reactions take place at room temperature and under normal atmospheric pressure. These conditions are likely to occur occasionally in

upper portions of ore deposits, and the discovery of Professor Young appears to offer a satisfactory explanation of the phenomenon.

Chalcocite occurs as rims and veinlets in chalcopyrite just as in bornite, but, so far as observations have extended, never in intergrowths with it. Chalcopyrite has not been found in the Virgilina ores as a replacement mineral in chalcocite.

ORIGIN AND DEPOSITION OF THE ORES.

General statement.—The facts in regard to the veins, the gangue minerals, the ore minerals, the relations of the minerals to each other, and the relations of veins and ores to the rocks in which they occur afford premises upon which to base certain theories in regard to the origin of the veins and the origin and deposition of the ores. In the discussions and descriptions on the previous pages the writer has endeavored to confine himself primarily to statements of fact and to recording such observations in regard to the geology and ore deposits of the Virgilina district, drawing such conclusions and offering such explanations as appeared to be obvious and to be warranted by the observations. In this place he will attempt to offer such theoretical conclusions and submit such explanations in regard to the origin of the veins, and the origin and deposition of the ores as, in his judgment, the foregoing descriptions warrant. He is fully aware of the size of the questions as well as their complexity and offers his theories and explanations only as a possible solution, leaving to future students the final solution of the problems.

Origin of the veins.—The origin of the veins has been discussed in a general way in the first part of this chapter, in advance of the detailed discussion of their mineralogy. Since the minerals of the veins and their relation to each other have such an important bearing upon the subject, in fact, are the very premises upon which theories and conclusions in regard to the origin of the veins must be based, it was decided to postpone the detailed discussion of, and the proposal of theories relative to, the subject until those items had been considered in detail.

It has been shown in the chapter on the description of the rocks that the rock in which all the mineralized veins occur is basic in character, having the mineralogical and chemical composition of andesite. It has also been shown in the descriptions of the individual veins and in the discussion of their mineralogy in this chapter, p. 68 *et seq.*, that their predominant mineral is quartz, and that one of their minor, but persistent,

minerals is orthoclase. Both of these minerals are foreign to or occur very sparingly in rocks so basic as the andesitic material forming the Virgilina greenstone. It has also been shown that the veins are much younger than the Virgilina greenstone in which they occur and that they were not formed until the tuffs and flows which make up the greenstone had been consolidated, folded, mashed, and metamorphosed into schists. These facts all indicate that a very long period of time elapsed between the building up of the andesitic tuffs and flows, and the formation of the veins. Furthermore it has been shown that, so far as it was possible to determine, the normal Virgilina greenstone does not contain even a trace of copper. It has also been demonstrated that the veins were developed in fractures, possibly fault planes which intersect the schistosity of the greenstone at acute angles, and which, therefore, were not formed until after the rock had become a schist. All these facts indicate clearly that a source for the vein matter, both gangue and ore minerals, must be sought entirely outside of the rock in which they occur, the Virgilina greenstone. Such source must be a rock or magma which could normally supply the highly siliceous gangue minerals, quartz and orthoclase, as well as the ore minerals, and at the same time provide for the formation of the other gangue minerals, such as epidote, chlorite, calcite, and plagioclase feldspars. The only rock in the district, or in the region for that matter, which fulfills all these conditions is the granite. It is therefore believed that the veins were derived from the granitic magma and that they were formed as a concomitant phenomenon, probably contemporaneous with its intrusion or following immediately thereafter when the cooling magma would be giving off its emanations. It is also believed that the sulphides, the orthoclase, the greater part of the quartz, and possibly the plagioclase feldspars, were derived directly from the granitic source, and that the other minerals were derived largely from the country rock through alteration of its normal minerals. The causes for deposition are believed to have been such factors as decrease in temperature and pressure of the rising solutions, their commingling with other solutions, and the influence of the wall rock of the fissures through which they were moving.

It is also believed that the vein-forming solutions did not find open cavities in which to deposit the vein matter. It is not understood how such cavities could possibly remain open under the conditions which seem to have prevailed during the formation of the veins. It is believed, however, that the solutions rising through the fractures widened them into the present veins through the forces of crystallization of the growing minerals



(A) Photomicrograph of a polished section of ore from the Wall mine, x 40. Shows graphic intergrowth of bornite and chalcocite, believed to be of hypogene origin. A few small fractures may be noted in which supergene, secondary chalcocite has formed. These fractures are clearly younger than the graphic intergrowths and so far as could be determined have had no influence upon their development.

Light areas = chalcocite.
Dark areas = bornite.



(B) Graphic intergrowth of bornite and chalcocite, x 220. This figure represents an area of the finely intergrown portion of the section shown in (A), but much more highly magnified.



(C) Graphic intergrowth of bornite and chalcocite, x 220. This figure represents a portion of the intergrowth shown in (A), which has been deeply etched with nitric acid, and then highly magnified. It shows by the "etch figure" of the chalcocite—the straight lines which intersect each other at right angles—that the portion of this mineral here seen is a single grain or crystal, and offers strong evidence that the two minerals are of contemporaneous deposition.



.05 mm

- (B) Photomicrograph of a very highly magnified area of the section shown in (A). It may be noted that two types of structure are shown, one decidedly lamellar, and the other, normal graphic intergrowth, shows a very marked resemblance to pearlite in steel. Pearlite consists of a kind of mechanical mixture of ferrite (free alpha iron) and cementite (Fe_3C) to which Howe applied the term eutectoid. The two constituents in pearlite certainly solidify contemporaneously as the melt cools. In the case of the sulphides here shown it is not known whether or not the two were deposited contemporaneously, but it is made clear by etching the polished surface that the intergrowth is along crystallographic directions—cleavage or parting planes in the chalcocite, and that it is therefore a crystallographic intergrowth. It is also interesting to note the extremely minute lines of chalcocite crossing through the bornite and joining adjacent lamellæ of chalcocite.

White = chalcocite. Dark = bornite.



2 mm

- (A) Photomicrograph of a polished section of ore from Cornfield Prospect No. 1, showing graphic intergrowth of chalcocite and bornite. This intergrowth is believed from general relations to be of hypogene origin, but there is no way of proving that such is the case. If of supergene origin it offers strong evidence that in this case the alteration has been from chalcocite to bornite, it being noted that the bornite occurs in what appears to be a fracture in the chalcocite. This section is another good bit of testimony that the evidence afforded by graphic intergrowths as to the origin of the components is, to say the least, ambiguous.

White = chalcocite. Gray = bornite. Black = pits.
Intersecting lines = scratches made in polishing.

of the vein, and through replacement of the wall rock by vein matter. It is also probable that the openings may have been increased by earth movements, faulting, etc., along the fractures in which the veins were forming.

Deposition of the ore minerals.—The relation of the different sulphides to each other has been discussed in detail in another place in this chapter and need not be repeated here further than to state that the ore minerals, bornite, chalcocite, and chalcopyrite are of two periods of deposition. During the first of these periods the original ore minerals were deposited from deep-seated, probably hot, solutions derived from a magmatic source believed to have been the granite. The ore minerals thus deposited are the so-called hypogene minerals; and consist of bornite, chalcocite, chalcopyrite, and minor amounts of other sulphides, such as pyrite, klaprothite, argentite, etc. So far as the writer has been able to determine there was only one period of hypogene mineralization, but it was probably of considerable length, and it is not known that conditions remained unchanged or that the active solutions were the same throughout the period. One thing, however, is certain: The minerals believed by the writer to be of hypogene origin as they are found to-day invariably bear exactly similar relations to each other, entirely regardless of the mine or portion of the district from which they are taken. It must be remembered that the three important hypogene minerals, bornite, chalcocite, and chalcopyrite, and possibly some of the minor sulphides, also occur as replacement minerals of supergene origin. These, however, always have their own peculiar characteristics which are very different from those of the same minerals which are believed to be of hypogene origin. It is therefore clear that in attempting to decide to which type of mineralization any particular specimen of ore belongs, the question must be decided upon the relations of the component minerals of the ore to each other instead of upon the presence or absence of certain minerals, taking into consideration, of course, the location in the vein from which the specimen was taken. The features which the writer believes to be clearly indicative of hypogene origin of the different sulphides are the various types of complex and graphic intergrowth between the component minerals, and the relation of sulphides to gangue minerals. These have been described in detail on pp. 82-87.

During the second period of deposition, also an extended period beginning when the ores first came under the influence of the agencies of weathering and continuing until the present, the same major sulphides, chalcocite, bornite, and chalcopyrite, were deposited as were formed during

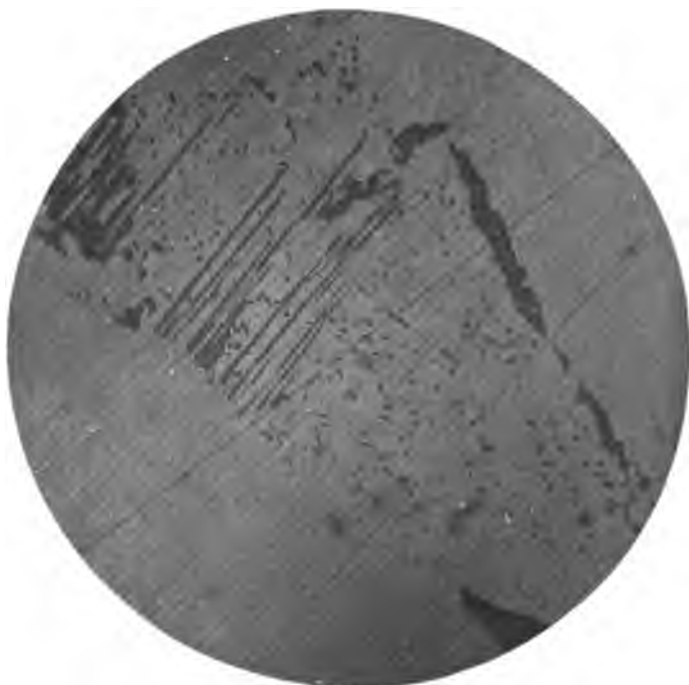
the first period of deposition. It is not known whether or not either of the minor sulphides, pyrite, klaprothite, or argentite, was formed during this period. The conditions under which these second period or supergene minerals were formed are entirely different from those of the first, or hypogene period. The supergene minerals were deposited by downward-moving meteoric waters, and are consequently limited to the upper portion of the veins, not extending below the depths reached by such waters. The minerals thus formed bear definite relations to fractures and other openings which permit the circulation of the downward-moving water, and, consequently, their relations to each other and to the minerals in which they occur are very different from those of the hypogene minerals. They always represent alterations in the hypogene sulphides in which they occur and usually are found in fractures and surrounding openings in the host mineral. The subject, however, has been discussed in detail on p. 73 *et seq.*, and need not be repeated here.

The most interesting and at the same time the most puzzling feature of the Virgilina ores are the graphic intergrowths described on pp. 82-89. Their interpretation is not only of great interest and value to the science of ore deposits, but is also of much value in forming estimates as to the continuation of the ore deposits with depth, and therefore of great value in forming estimates as to the future of the district as a whole. It, therefore, seems best to summarize the principal theories that have been offered as explanations of them.

The first theory thus presented was given by the writer^a in his paper on the ores and minerals of the district in 1911, and it is the one to which he still holds after having made an exhaustive microscopic study of the subject. It is, that the intergrown bornite and chalcocite are both hypogene or primary minerals and that they are of contemporaneous deposition.

The writer believes that such crystallographic intergrowths are formed only when the component minerals are of contemporaneous deposition, and that they are similar to the same type of intergrowths in pegmatite, other sulphide intergrowths, such as sphalerite and pyrite, galena, argentite, and bismuthinite, galena and stibnite, and many others, and to the eutectic and eutectoid intergrowths of sulphides in mattes and of metals in alloys, all of which produce the same type of pattern. So far as the writer's experience has extended such intergrowths have never been found to have formed as the result of supergene agencies and processes.

^a Laney, Francis Baker: The relation of bornite and chalcocite in the copper ores of the Virgilina district of North Carolina and Virginia, *Proc. U. S. Nat'l Museum*, Vol. 40, 1911, pp. 413-424; *ibidem*, *Economic Geology*, Vol. 6, 1911, pp. 399-411.



.1 mm

- (A) Photomicrograph of a polished section of ore from Cornfield Prospect No. 2. Shows chalcocite of two distinct shades of color, one a delicate bluish gray, and the other normal. The bluish gray chalcocite is in graphic intergrowth with bornite which shows in the photographs as irregular areas, as minute dots, and in elongated rod-like forms. The two chalcocites are not clearly differentiated from each other in the photograph, but are easily distinguishable by the eye. The evidence as to the origin of such structures is not conclusive, but the writer believes the minerals were deposited contemporaneously.

Light gray = chalcocite. Dark gray = bornite.



.1 mm

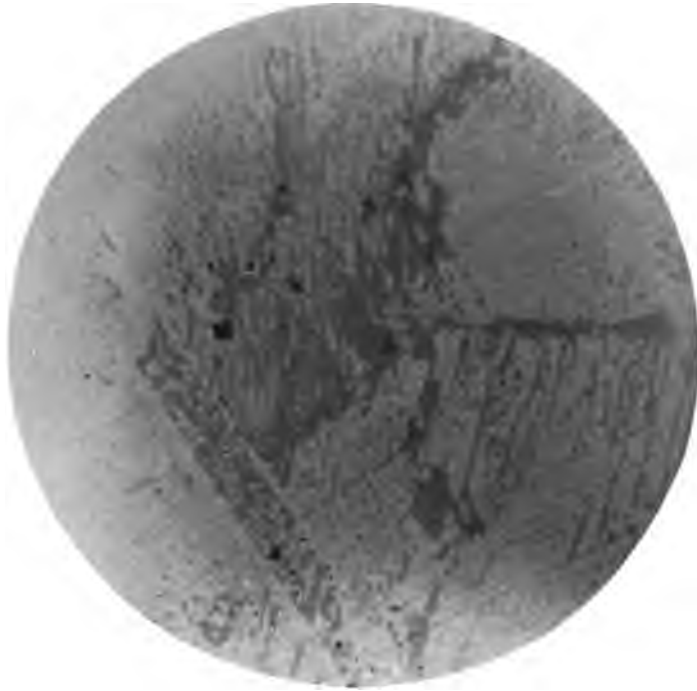
- (B) Photomicrograph of another portion of the section shown in (A). Shows a different pattern of the reticulated graphic intergrowth between chalcocite and bornite.

Light gray = chalcocite. Dark gray = bornite.



.05 mm

(B) Photomicrograph of a portion of the same section shown in (A), but very highly magnified in order to show the intricacy of the reticulated intergrowth. Light gray = chalcocite. Dark gray = bornite.



- (A) Photomicrograph of a polished section of ore from Cornfield Prospect No. 1. Shows reticulated intergrowth of bornite and chalcocite. By etching the section it shows clearly that the minerals are intergrown along crystallographic directions. Such occurrences as this add to the difficulty of accounting for the formation of the graphic intergrowths as characteristic of the Virgilina ores. In the present instance there are reasons for believing them to have resulted from supergene agencies, but there is no proof that they are not of hypogene origin and that the two minerals were deposited contemporaneously.

Light gray = chalcocite. Dark gray = bornite.

A second theory is, that the bornite in the intergrowths is a primary mineral and of hypogene origin, and that the chalcocite represents a secondary alteration of the bornite but that it is of hypogene origin. That is, the adherents of this theory believe that the chalcocite is a secondary mineral formed by deep-seated agencies.

So far as the writer can see, there is no way of either proving or disproving this theory. He has studied in great detail secondary hypogene alterations in the silver ores of Tonopah, Nev. The patterns there formed by such processes are similar to those formed in ordinary supergene enrichment. He therefore believes that the adherents of this theory must prove that such patterns can and do result from hypogene alterations in earlier hypogene sulphides before they can apply it in explanation of these intergrowths.

A third theory is that the bornite is a primary or hypogene mineral, and that all the chalcocite is a replacement of the bornite and of supergene origin.

It is felt that before the adherents of this theory can offer it they must first explain how the same agencies acting under the same conditions can produce such different and characteristic results as the chalcocite which occurs as replacement veinlets in the bornite on the one hand and the graphic intergrowths on the other. Furthermore, so far as the writer is aware, such graphic intergrowths have never been shown to result from supergene agencies.

A fourth theory, offered by Segall^a as an explanation of certain reticulate crystallographic intergrowths in the Butte, Mont., copper ores, is that such intergrowths are the result of replacement of chalcocite along crystallographic directions by bornite.

Each of these four theories has its ardent adherents, but so far as the writer's judgment goes, neither theory has been proven nor disproven. As stated above and fully realizing the strength of the other theories, he believes that in such graphic intergrowths as those characteristic of the Virgilina ores, the evidence points more strongly toward contemporaneous deposition of the two minerals and he still adheres to that theory.

CONTINUATION OF THE ORE DEPOSITS WITH DEPTH.

The descriptions and generalizations in regard to the rocks, the veins, and the ores, and the geological structure of the Virgilina district as

^aSegall, Julius: The origin and occurrence of certain crystallographic intergrowths, *Economic Geology*, 1915, Vol. 10, pp. 462-470.

given in foregoing portions of this report appear to the writer to warrant a few statements and surmises as to the continuation of the ore deposits with depth.

It has been shown that all the geological evidence in regard to the subject indicates that the veins and ores have been derived from deep-seated sources, probably from an intrusive magma entirely independent of the greenstone in which they occur. It has also been shown that the veins were developed in fractures, possibly fault planes, which extend to unknown, but certainly great, depths. When these factors are considered together it is reasonably certain that the ore deposits are by no means merely superficial phenomena and that they will extend to depths beyond the limits of mining. While there is no means of proving it, the writer regards it as reasonably certain that the intergrown chalcocite and bornite are hypogene minerals of primary deposition and therefore that there will be no change to leaner minerals with depth. It is not intended to assert that any one ore shoot will continue to indefinite depth, for such a statement would be preposterous. What the writer believes and what he intends to say is that the veins with all their irregularities as to width and metal content will probably continue to great depths. The size and value of an ore deposit as shown in reasonable development may form a basis upon which to base expectations as to what further exploration may develop. It is, therefore, the writer's opinion that if the upper 300 or 400 feet of development work in an ore shoot develops ore of commercial value, the ore thus developed will form a basis for expectations as to what further exploration would develop and that the development may be carried forward to great depths with reasonable hope of success.

THE MINES AND ORES OF THE VIRGILINA DISTRICT

DESCRIPTIVE GEOLOGY OF THE MINES AND PROSPECTS.

SEABOARD MINE.

General statement.—The Seaboard mine, owned by the Seaboard Copper Company, of Boston, Mass., is located on the west one of two approximately parallel low-lying, flat-topped ridges extending northeastward from the center of the Virgilina district. It is about four and one-half miles northwest of the town of Virgilina, located on the Danville and Norfolk Division of the Southern Railway, which is the nearest shipping point. It is reached by a good wagon road and is so located that a branch line connecting it with the main line of the railroad at Virgilina could be built at minimum expense. The country adjacent to the mine is fairly well timbered with both pine and oak, and there is an abundant supply of material for mine timber, lumber, etc. There is not an abundant supply of water for the mine, but a small stream about three-fourths of a mile southeast could be made to furnish an ample supply by the building of a dam and installing pumps to send the water from the stream to the mine. In fact, a small dam has been built at a suitable place on this little creek and the water which was used in the development of the mine was pumped from this place.

Copper is said to have been first found on this property in 1899, and between this date and 1902 two shafts, Nos. 1 and 2 of the company, were started and each sunk to a depth of about 100 feet. This early work was done by a Mr. Williams and consisted of little more than prospecting. In 1902 the property was purchased by its present owners, who at once proceeded to sink a new shaft, No. 3, and to continue work in shaft No. 2. No. 2 shaft was sunk to a depth of about 260 feet and drifts were broken off from it at the 100- and 200-foot levels, respectively. The work thus far done amounts to about 600 feet of drifts in addition to the shafts, and was all done for development purposes, and no ore was taken out except that which came from the development work.

Description of vein.—The ore-bearing ground consists of a well-defined quartz-epidote vein carrying a small amount of calcite. This vein varies in width from one and one-half to eight feet, averaging three and one-half

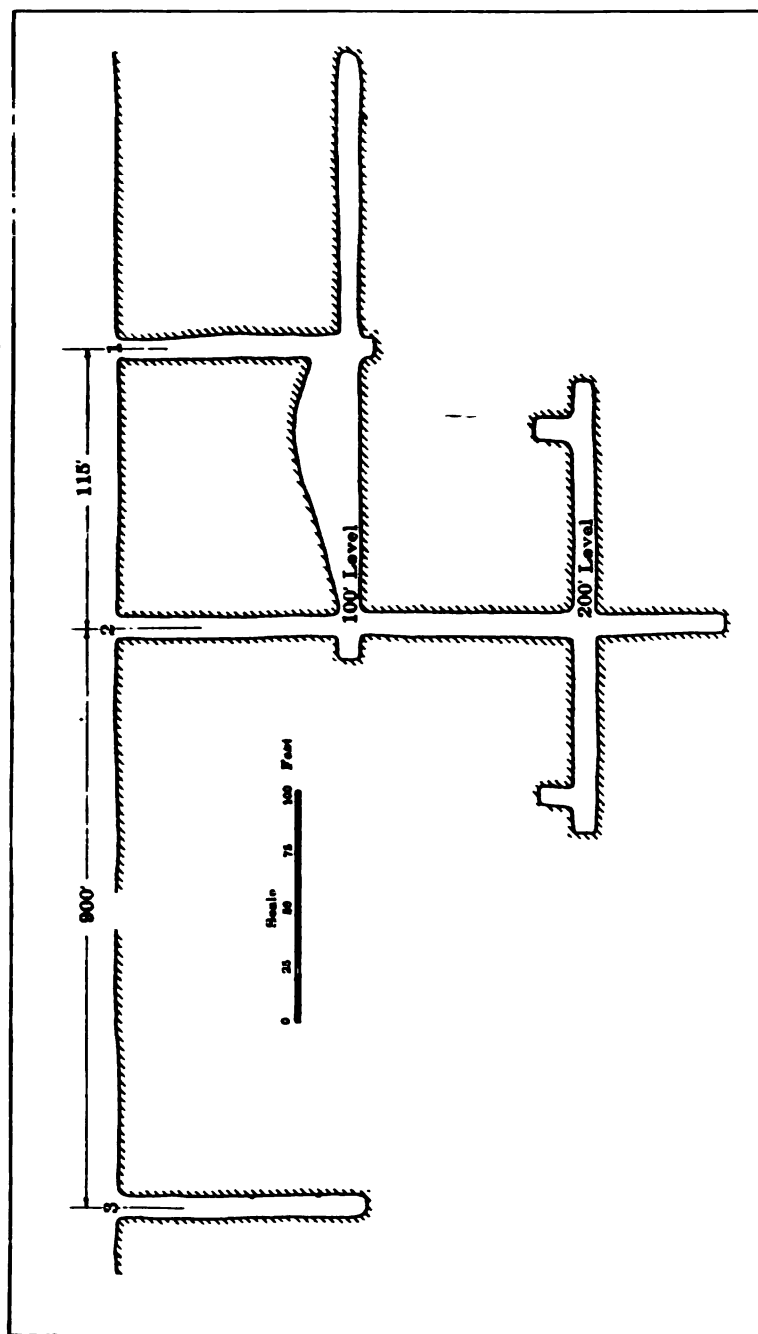


Fig. 2.—Vertical section of Seaboard mine. Surveyed by T. W. Sprague, 1900.

to four feet, and is traceable on the surface by means of quartz débris for a distance of about one and one-half miles. Three ore shoots have been located, one at shaft No. 3, one at shafts Nos. 1 and 2, and the third about one-half mile north of shaft No. 2 near the public road running west from Red Bank. Of these ore shoots only that at shafts Nos. 1 and 2 has been developed to any important extent; the others, however, especially that at shaft No. 3, appear to be fairly well mineralized and to warrant further development. In addition to this, the main vein, there is another well defined but smaller vein lying about 200 feet west. This west vein is well marked by quartz and epidote on the surface and is traceable for about three-fourths of a mile, and has been opened by a shallow shaft about 1,200 feet south of shaft No. 1. This prospect opening showed the vein to be narrow but to carry a small percentage of copper. Both veins have a strike of from 5 to 10 degrees west of north and dip about 80 degrees to the east. The schistosity of the country rock strikes approximately north and south, and it is thus seen that the veins cut the schistosity at sharp angles. They are believed to be true fissure veins and to have been developed in fractures which, as a rule, in this district have a more northerly trend than the schistosity of the country rock, though in many instances their trend is parallel with the schistosity. These veins have well-defined walls and part readily from the country rock. However, in places there is a small amount of mineralization of the wall rock at its contact with the vein. As is usually the case with veins in this region, these present many irregularities, the most important of which consist of "pinches" and "swells," both horizontally and vertically. The development at this mine has not gone far enough to show the extent of irregularities that have been noted, but there are decided "pinches" in at least two places with corresponding "swells" in two others. The veins are much more highly siliceous than the country rock, and are believed to have been derived from sources other than the rocks in which they occur. This subject, however, is discussed in the chapter on the origin of ores.

The ore shoots, so far as the development has proceeded, are well mineralized and appear to have a slight pitch to the south. The ore does not occur in any one portion of the shoot to the exclusion of all others. In some instances it is distributed rather uniformly throughout the vein. In others it is largely concentrated near one wall with only a small amount scattered irregularly through the rest of the vein, while in still others the principal values occur near the middle of the vein with only a small amount in other portions of it. There is always more or less barren material in

the vein, but it is so located that it can not be left in the ground in mining. The only structural feature affecting the developed portion of the mine appears to be a small fault which was encountered in the south end of the drift on the 200-foot level, at which point the vein appears to be cut out completely. All indications, however, are that the disturbance is slight and that the vein could probably be picked up again by drifting a few feet into the hanging wall at the end of the drift.

Ore and gangue minerals.—The ore at this mine consists of bornite and chalcocite together with a small amount of malachite in the upper portions of the vein. In certain portions of the ore shoot bornite appears to be more abundant than in any other mines of the district. In fact, the purest bornite found during the field investigations was taken from this mine. Much of the unaltered ore, however, like that from the other mines of the district, consists of bornite and chalcocite intergrown in such manner as to indicate that the two minerals were deposited contemporaneously. In the ore from the upper portions of the ore shoot much secondary chalcocite occurs in the bornite as veinlets varying from knife-edge seams to one-fourth inch in width. These penetrate the bornite in all directions and vary in size from the finest line, often scarcely visible even with the highest powers of the microscope, up to veins of pure chalcocite one-fourth inch in width. See Plate VIII (A and B). The centers of nearly all of the largest chalcocite-filled fractures are marked by sponge-like areas of some material, which in some instances appears to be quartz and limonite, and to mark the original fracture in which the chalcocite began to develop. In most cases these areas are of appreciable size and include particles of chalcocite and appear to have developed simultaneously with the chalcocite. Plate XIII (A and B).

When a polished section of ore showing these chalcocite veinlets is etched with hydrochloric acid and examined under the microscope, the material is seen to be porous and to resemble a sponge, and to be filled with minute specks of chalcocite. The boundary between these veinlets of secondary chalcocite and the bornite is generally regular, but the material within the chalcocite usually presents a somewhat feathery outline. The boundary line between the chalcocite and bornite is always perfectly clear cut and sharp, and there is absolutely no gradation of one mineral into the other. It is also clear from microscopic examination that each little vein of chalcocite in all probability started as a mere film in the fracture and grew to its present size, but how this growth took place is not made clear by microscopic

study of the veinlets. It does appear, however, that it took place at the periphery of the material already deposited, and that the veinlets increased in size at the expense of the bornite. However, the chemistry of the process has not yet been worked out. In some instances chalcocite-filled fractures in the bornite appear to be of two periods, one earlier than the other, and in such instances the more recent fractures cut across the chalcocite veinlets in the older ones. Fractures also occur in the areas of intergrown chalcocite and bornite, and in such instances the secondary veinlets cut across both the primary chalcocite and the bornite. The relations of the two minerals in such cases leave no doubt as to the secondary nature of the chalcocite in the veinlets.

The gangue minerals in this mine consist of quartz, epidote, calcite, chlorite, albite, and hematite. Quartz is by far the most important gangue mineral and makes up more than three-fourths of the vein. Calcite and epidote are present in about equal amounts, while albite, chlorite, and hematite are only sparingly developed. The greater part of the quartz is massive, and shows no tendency to form crystals. However, in some instances, especially in openings or vugs, quartz, calcite, and albite were found with good crystal development, and all were intergrown with the bornite and chalcocite. The peculiar association of gangue and ore minerals in this mine presents some features which have an important bearing on the genesis of the ores, and the subject is discussed fully in the chapter on this subject.

Development.—The development of this mine consists, as has been stated, of three shafts, Nos. 1, 2, and 3. Shaft No. 1 was the first to be sunk, and extends to a depth of 110 feet; shaft No. 2 is on the same vein, is located 113 feet south of shaft No. 1, and is the main working shaft of the mine. It is about 350 feet deep and from it two levels have been broken off, one at 100 feet and the other at 200 feet. The 100-foot level has been driven in the vein about 225 feet northward, intersecting shaft No. 1. The vein throughout this distance has an average width of about four and one-half feet and a copper content of approximately 2 to 2.5 per cent. The second level extends 105 feet north from the shaft and 90 feet south. On this level the vein is slightly narrower than at the first level, but the copper content is approximately the same. At the point where the second level was broken off from the shaft, the vein is narrow and not very promising, but at the bottom of the shaft it has widened considerably, has increased in ore content, and is much more promising.

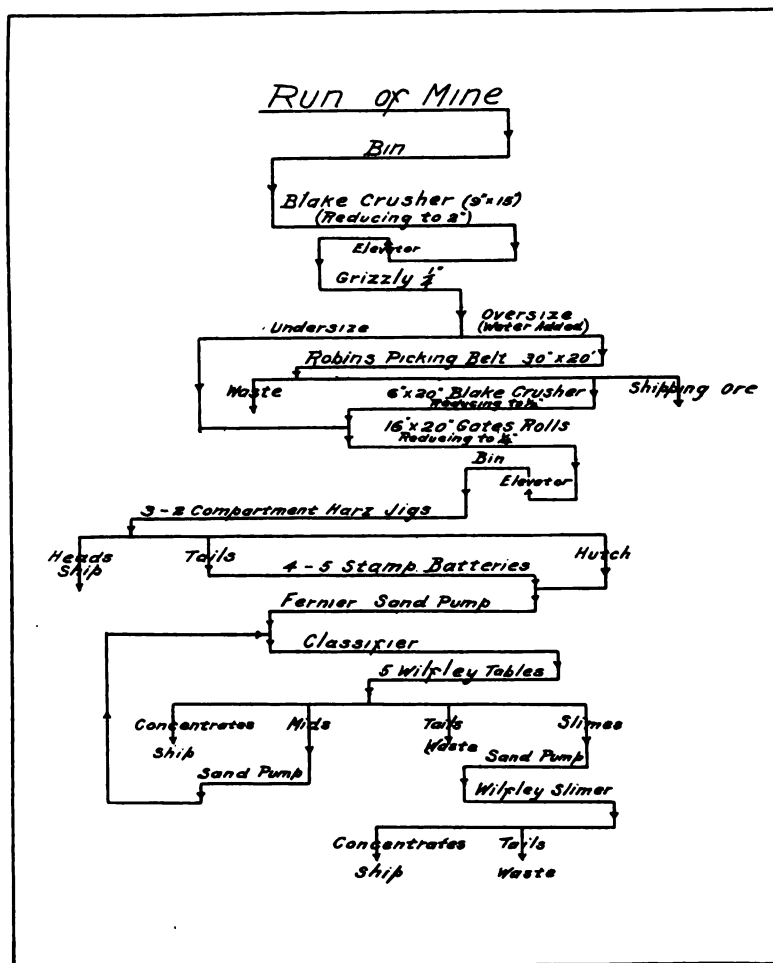


Fig. 3.—Flow-sheet of Seaboard mill as designed and constructed by A. W. Tucker, 1909.

Practically no ore has been taken from this shaft except that which was removed during the development work. Shaft No. 3 is 105 feet deep, is located about 900 feet south of shaft No. 2, and no drifting has been done. At the time of the field work this shaft was filled with water and, therefore, inaccessible. The ore on the dump, however, is entirely similar to that taken out of No. 2. No observations as to the width of this vein or the extent of the ore shoot could be made. However, it was reported that the vein is about 5 feet in width and fairly well mineralized. A generalized vertical section showing the development of the mine at the time the field work was in progress is shown in figure 2, page 96.

Concentrating plant.—It is generally agreed by those who have studied the ores of the Virgilina district that the future development of the district depends upon the ability to concentrate the ores. In order to solve the problem of concentration, which had been attacked in a desultory way at two or three mines in the district, the Seaboard Copper Company employed Mr. A. W. Tucker, of the Massachusetts Institute of Technology, and supplied him with the necessary ore for experimental work. This work, which was carried on in the laboratory of the Institute in Boston, gave satisfactory results, and in 1907 the company erected, under the supervision of Mr. Tucker, a 50-ton mill in which the ore is given the following treatment:

On being hoisted from the mine the ore passes through a rock breaker and is crushed to two inches, then passed over a picking belt from which barren material is rejected as waste, and ore approximating 10 per cent or more in copper is selected for direct shipment. The remainder is reduced to one-fourth inch by a crusher and rolls and is passed through a series of 4-compartment Harz jigs. From the jigs three products are obtained, a 50 per cent copper concentrate; a hutch product, which goes direct to a set of Wilfley tables; a middlings; and tail product, which goes to a battery of stamps and which, after being stamped through 60 mesh, is subjected to treatment on Wilfley tables. From these a 25 per cent copper concentrate is obtained. The slimes are collected and are run on Wilfley slime tables, the concentrates from which are added to that from the regular tables. No figures were obtainable which would give the total percentage of copper saved by the mill. However, in the experimental work in the Massachusetts Institute of Technology above referred to, a similar equipment to the one just described was used, and a saving of between 80 and 85 per cent of the assay value of the ore was obtained. The flow sheet of this mine, which was furnished by Mr. Tucker, is shown in figure 3, page 100.

The mill was operated only a short time, and the ore treated consisted of about 2,200 tons of second-grade material left over after hand picking. From this there was extracted about 77 tons of concentrates. Smelter returns from these were as follows: Hand-picked ore averaged 7.45 per cent copper, 1.50 ounces of silver, and .01 ounce of gold per ton, respectively. Table concentrates averaged 23.85 per cent copper, 2.89 ounces silver, and .02 ounce gold per ton.

While it is evident that the data just given are not sufficient to warrant any far-reaching statements as to concentration of the Virginia ores in general, it is believed that they do show conclusively that a properly constructed and operated mill will concentrate the ores in a satisfactory manner, and they also indicate that such a mill should be constructed somewhat along the lines of the Seaboard mill.

BLUE WING MINE.

General statement.—The Blue Wing mine is located about one and one-half miles southeast of the town of Virginia, from which it is reached by a good wagon road. The branch line of the Southern Railroad running from the junction about 1 mile east of the railroad station at Virginia to the Holloway mine passes within 100 feet of the Blue Wing shaft, and thus furnishes excellent shipping facilities.

While the timber lands surrounding the mine have been cut out, there is still an ample supply of both hardwood and pine for mine timbers. At the time of the field work there was such an abundant supply of cord wood that the mine management found it a much cheaper fuel than coal.

There is only a moderate supply of water, which is derived from a small brook near the mine. In winter and spring the supply is ample, but during the late summer and fall, the dry season in the region, the brook is often dry and water for mining or milling purposes is scarce. However, it is believed that by impounding the water during the spring there could be provided at small expense a supply sufficient for all actual needs during the dry season. In case this water should fail, it is certain that an ample supply could be obtained by pumping from Aaron's Creek about one and one-half miles east of the mine.

The mine takes its name from Blue Wing post-office, long since abandoned, which was located a short distance west of the mine at the time of its opening, and which in turn received its name from Blue Wing Creek located about 2 miles west of the post-office. It is reported that during the year the mine was opened about 500 tons of high-grade ore

were taken out and shipped. The property after passing through several hands was acquired about 1895 by its present owners, the Boston and Carolina Copper Company, a Massachusetts organization maintaining offices in Boston. It has been operated spasmodically rather than steadily, and has been allowed to lie idle the greater part of the time. The causes for this idleness, so far as they could be determined, appear to have been litigation, certain transactions looking toward a consolidation of the more important mines of the district which the company was trying to effect, and the varying price of copper. There has never been a time since the discovery of the mine when it would not have been regarded at least as a very favorable prospect. The causes for so much intermission in operation are thus attributed more largely to market, financial, and other conditions affecting the operators than to the lack of ore in the mine or of promise in the prospect. The last work was done in 1909 by E. H. Westlake of the Tennessee Copper Company under an option granted by the owners of the property. Under this agreement the mine was operated, but not continuously, from July 1, 1909, to January 1, 1910, and about 3,000 tons of ore were shipped which averaged between 2 and 3 per cent of copper. During this work the shaft was sunk an additional 80 feet, giving it a total depth of 360 feet and about 400 feet of new drifts were driven.

The surface plant consisted of the housing for the shaft and the necessary machinery for operation, consisting of a steam boiler, a small hoisting engine, a good 10-drill air compressor, picking belt, and equipment including a rock breaker. There are also bins for storing about 100 tons of ore, and a repair and blacksmith shop.

Nothing in the way of concentration has been done during recent years except such sorting of ore and elimination of waste as could be done on a picking belt, which work was done efficiently and cheaply by negro women. It is reported that in the early days of the mine crude attempts were made at concentrating the ore. The plant for this purpose is said to have consisted of the necessary crushing equipment, a set of Harz jigs, and a Frue vanner. The equipment was so meager and ill adapted to the ore, and the work was done in such a desultory way, that it proved a decided failure and was soon discontinued. This failure must not be taken to indicate that the ores are not amenable to concentration, for from experimental work, and also from actual mill practice on other ores of the district similar in all respects to the Blue Wing ore, it is certain that with modern equipment and intelligent management these ores can be concentrated without difficulty.

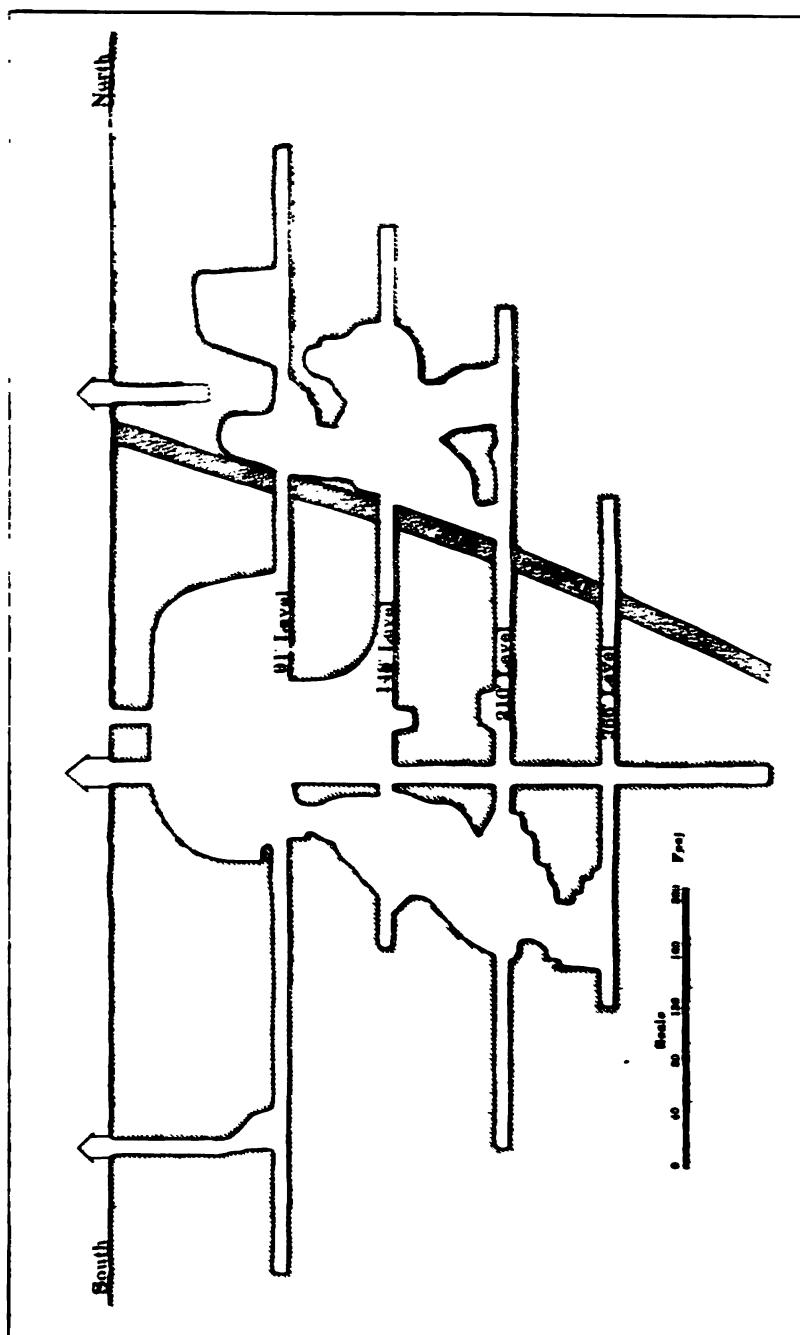


FIG. 4.—Vertical section of Blue Wing mine. From surveys by J. Parke Channing, 1906, and R. W. Linsler, 1910.

Underground development.—The property has been tested and developed by one working shaft about 360 feet deep, 3 prospect shafts varying in depth from 50 to 125 feet and about 1,700 feet of drifts, which were broken off from the main shaft at four levels: 91 feet, 148 feet, 210 feet, and 266 feet, respectively, from the surface. Considerable stoping has also been done in what appear to be two distinct ore shoots, one at the main shaft and another immediately north of the diabase dike which crosses the vein about 120 feet north of the shaft. In the first-mentioned ore shoot the stoping extends from about 30 feet from the surface to the 260-foot level and in the second from about 50 feet from the surface to the 210-foot level. Nothing in the way of exploratory work except the shaft has been done in ground deeper than the 266-foot level, although all indications are that the two ore shoots will probably extend to a much greater depth than has been reached by any of the present workings. The vein varies from about 2 to more than 6 feet in width, averaging perhaps 4 feet, and the values are distributed irregularly through it, with sometimes portions of the walls being mineralized. Consequently, in order to be certain of obtaining all the values in drifting and stoping, it is always necessary to remove the entire vein, and, in some instances, a considerable portion of the walls. The drifts and stopes, therefore, represent at least the actual width of the vein and show the irregularities as to outline that it presented. A vertical section through the mine showing the development up to 1910 is shown in figure 4, page 104.

Only the usual and well-known methods of mining were used in this mine. Modern air drills were used in sinking and driving, and together with light stoping drills furnished the equipment for use in breaking the ore. Both the overhead and underhand methods of stoping were employed, the one being used which was most suitable for the ground to be removed. The mine apparently makes only a moderate amount of water, which was easily handled with a small Cameron pump. The broken ore was trammed to the shaft, hoisted in buckets, and dumped in a bin about 20 feet above the collar of the shaft. From this bin it was passed through a rock breaker and reduced to 2 inches, and then passed over a grizzly which removed all material less than 1 inch. The oversize went on the picking belt from which the waste rock was removed; the ore then passing into bins from which it was shipped.

Geologic relations.—The country rock at the Blue Wing mine is the typical greenstone schist of the district, and does not differ essentially

from the rock at the Holloway, Durgy, and Seaboard mines. Technically speaking, the rock is a mashed and much-metamorphosed andesitic tuff, associated with which is a small amount of normal andesitic lava which in some places is slightly porphyritic and in others decidedly amygdaloidal. The intense metamorphism to which the rock of the district has been subjected has to a large extent obliterated its original characteristics and

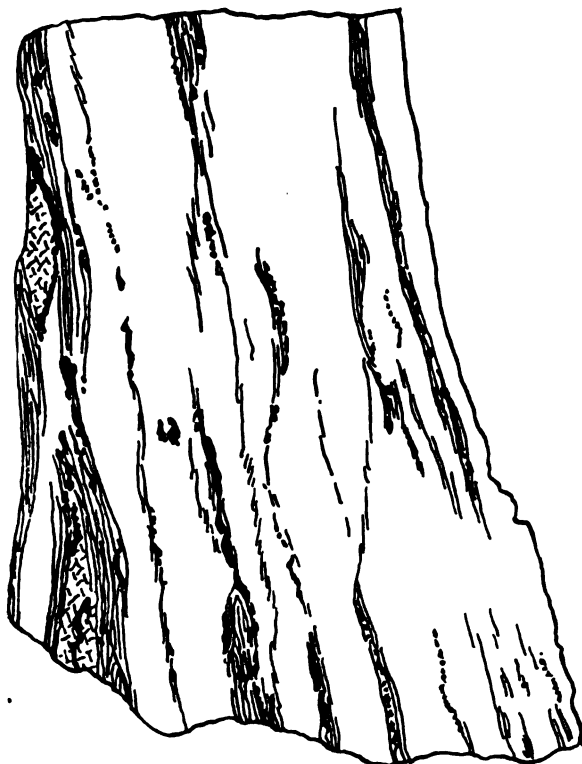


Fig. 5.—Ore from Blue Wing mine, showing banded structure. The white ground is calcite, with some quartz in little lenses. The solid black is bornite. The parallel lines represent schist. Scale, natural size. (After W. H. Weed.)

transformed it into a chlorite-epidote schist which varies in color from dark green to a purplish-gray. It almost invariably has a decided slaty cleavage or schistosity, which in the vicinity of the Blue Wing mine has a trend of from 20 to 30 degrees east of north and dips from 70 to 80 degrees toward the southeast. This subject, however, is discussed in the chapter devoted to the detailed description of the rocks of the district.

There is at this mine an interesting phenomenon that occurs at only one other mine in the district, namely, the Durgy mine. This is a dike of olivine diabase about 15 feet wide, which cuts across the vein some 150 feet north of the shaft. The dike trends approximately north 35 degrees west and dips about 65 degrees to the southwest. Thus, as the shaft is increased in depth, it necessarily approaches nearer the dike, and, unless the dip of the latter changes, will intersect it at a depth of about 425 feet. The intrusion of this dike followed the development of the vein and ores at a great interval of time and is believed to have had no influence in the formation of the vein or ores. The only effect noted so far as the mine has been developed consists of a slight shattering of the vein at the contact between it and the dike, and in a few places by slight displacement on the north side of the dike. This displacement is especially noticeable on the fourth level, where the vein is badly shattered and apparently displaced about 8 feet toward the east.

The vein is a typical fissure vein, and is made up dominantly of white quartz with much calcite and variable amounts of epidote, chlorite, and a few other minerals. The vein, which varies in width from 2 to 6 feet, will average about 4 feet, and, while locally it appears to follow the schistosity of the country rock, taken as a whole, it has a somewhat more northerly trend than the schistosity. It presents many irregularities in shape and form, but maintains its average width with much persistence. Within it are included many fragments and strips of more or less altered country rock, and in many instances it presents a decidedly sheeted appearance caused by the vein matter filling spaces between the torn-apart or rifted schists. As a rule, both foot and hanging walls are well defined, although in places one or the other is rendered obscure by the development of numerous layers or plates of vein matter in the rifted schist. The foot-wall is probably more clearly defined and is more easily followed in mining than the hanging wall. However, as a rule, both walls are well defined. The ores are almost exclusively confined to the vein, but there is always a varying, and in some instances a considerable, amount of ore in the wall rock near the contact with the vein. In mining it is, therefore, always necessary to keep close watch of the walls in order to be certain that no values are left. The vein possesses many irregularities in the way of pinches and swells, and contracts and widens in both vertical and horizontal directions.

Ore and gangue minerals are of contemporaneous development, and there is little or no supergene or secondary enrichment, at least none of importance from a commercial standpoint. While there is a tendency

toward segregation of the quartz and calcite in the vein, in no place has it been carried to completion, and each mineral is intermixed and intergrown with the other and with the ore.

The following minerals, exclusive of included country rock, named in the approximate order of their abundance, make up the gangue minerals of the vein: Quartz, calcite, chlorite, epidote, and hematite. The ore minerals in the order of their abundance are: Bornite, chalcocite, malachite, azurite, and argentite(?). It is not definitely known how the silver occurs in the ore, but microscopic examination of polished sections offers some evidence that it is present in the form of argentite, and that it is intergrown with the other sulphides. Ore and gangue minerals are so intimately asso-

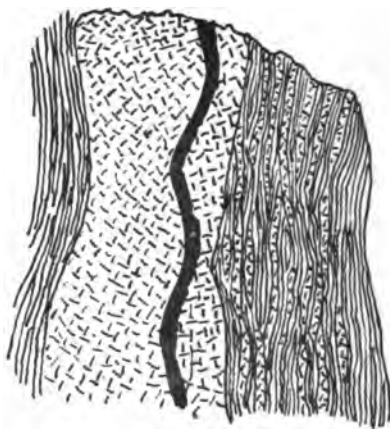


Fig. 6.—Blue Wing vein, face of 100-foot level, north. On the right is schist with stringers of quartz. In the center is calcite with some quartz and a streak of ore. On the left is calcite and quartz, then schist. (After W. H. Weed.)

ciated and intergrown with each other that there is little doubt that they are of contemporaneous development. There is a slight tendency on the part of the ore to be segregated in different portions of the veins, but in no place is it completely so, and in general a good part of the ore is found bunched here and there throughout the vein, while a smaller amount is scattered irregularly through it. There is also often an important development of ore in the schists at or near the contact with the vein. An important feature of the deposit from both a commercial and scientific standpoint is the predominance of quartz as a gangue mineral. Many carefully made estimates and analyses show that the vein carries an excess of silica varying from 60 to 70 per cent, thus making it possible to use the ore as

converter linings and as a siliceous component in smelting other heavy sulphide ores. In fact, this feature is common to all the ores of the district and forms a very important consideration in its future development. The following partial analyses of selected samples of the ore, which were made for commercial purposes, show in a general way the composition of the ore.

Partial Analyses of Selected Samples of Blue Wing Ore.^a

	A	B
	<i>Per cent</i>	<i>Per cent</i>
Cu	2.73	4.10
Fe	6.10	6.50
CaO	5.65	7.10
S	0.91	1.46
Al ₂ O ₃	6.89	1.10
MgO	0.79	0.56
SiO ₂	66.84	69.00
Ag	0.80 oz. per ton	1.30 ozs. per ton

From the standpoint of genesis of the ores their highly siliceous character indicates that they are probably derived, not from the basic greenstones in which they are found, but from some extraneous, highly siliceous rock, in all probability from the granitic intrusions which occur abundantly in certain parts of the district. This question is discussed in detail in the chapter on the origin and deposition of the ores. The general character of the vein and the relation of ore and gangue to walls and country rock are well illustrated in the following sketches by Weed.^b Figure 6 represents, natural size, a typical specimen of ore, showing banded structure caused by the inclusion of layers of schist and illustrates the distribution of ore through the gangue. Of figures 6, 7, and 8, Weed says: "Fig. 6 shows the face at the north end of the 100-foot level; Fig. 7 the roof above the stope, a short distance south of the face. Fig. 8, a sketch of the south face of the same level, shows quartz lenses holding ore and the slate-casing to the ore lenses. This south face shows on the hanging wall barren white quartz and calcite, and on the foot dark gray sulphide in slate with quartz streaks holding parallel threads or films of what looks like slate dotted with ore. Ore (harder and darker in color) also occurs in the casing. The ore body often presents a streaked or ribboned appearance, due, not to crustification or to recent movement of the vein, but to partly replaced sheets of slate."

^a U. S. Metals Refining Company.

^b Weed, Walter H.: Types of copper deposits in the Southern United States, *Am. Inst. Min. Eng., Trans.*, Vol. 30, 1900, pp. 465-467.

The general tenor of the ore is well shown by the following tables of smelter returns on actual shipments of ore. These shipments were selected to represent the type of ore taken from the mine at different periods in its development. They represent the returns for ore taken out in 1899 to 1900, which is selected and cobbled ore rather than the run-of-mine, and consequently shows a much higher percentage of copper than the average of the vein. The table showing the returns for 1907 represents the run-of-mine ore with only such waste material as was removed on a picking belt, and is believed to represent the average ore of the mine.

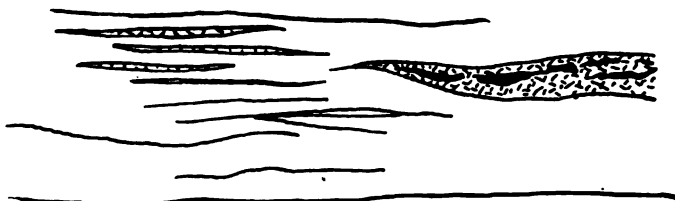


Fig. 7.—Sketch of Blue Wing vein in roof over stope above the 100-foot level, 350 feet south of shaft. On the left, calcite and a little white quartz, with dark streaks of slaty material and spots of ore. On the right, ore in dark quartz. (After Weed.)

Assays of Blue Wing Ore, 1899-1900.

Lbs. Sampled	Date	Cu. Per cent	Ag. Ozs.	Au. Ozs.	Assayer
42,885	May 12, 1899	11.91	N. d.	N. d.	Ledoux and Co.
43,341	June 3, "	11.31	"	"	"
46,075	" 10, "	12.40	"	"	"
50,276	July 14, "	11.70	"	"	"
43,907	" 21, "	12.38	"	"	"
43,881	Aug. 8, "	13.85	"	"	"
41,514	Sept. 9, "	12.69	"	"	"
31,705	Nov. 24, "	7.35	"	"	"
41,193	" 21, "	11.04	"	"	"
49,823	Dec. 30, "	15.64	5.55	"	"
5,289	Sept. 12, "	42.48	N. d.	"	"
54,879	" 12, "	3.76	"	"	"
39,879	" 11, "	3.56	"	"	"
66,772	Oct. 7, "	10.27	"	"	"
3,063	Dec. 30, "	44.48	13.80	.01	"
36,340	Jan. 20, 1900	6.48	N. d.	N. d.	"
54,051	Oct. 19, 1899	8.33	"	"	"

Assays of Blue Wing Ore, 1907.

Lbs. Sampled	Date	Cu. Per cent	Ag. Ozs.	Au. Ozs.	Assayer
44,160	July 20, 1907	6.81	2.65	.0066	Eustis Smelting Works
327,250	" 5, "	3.17	1.18	.005	"
298,184	" 9, "	3.09	1.16	.005	"
354,917	" 20, "	2.69	1.02	.994	"
337,548	" 20, "	2.69	1.00	.004	"
369,685	" 27, "	3.08	1.17	.005	"
389,027	" 29, "	2.66	1.00	.004	"
370,728	" 31, "	2.08	.80	.002	"
234,679	Aug. 5, "	2.46	.96	.005	"
198,230	" 9, "	2.47	.97	.004	"
373,814	" 9, "	2.31	.89	.004	"
345,465	" 22, "	2.39	.89	.004	"
217,191	" 22, "	2.42	.90	.004	"
322,720	" 22, "	2.67	.95	.0045	"
363,699	Sept. 1, "	2.67	.96	.005	"
221,132	" 3, "	2.96	1.07	.005	"
326,477	" 3, "	2.75	1.00	.005	"
312,586	" 9, "	3.26	1.14	.005	"
232,525	" 4, "	4.21	1.54	.015	"
309,108	Oct. 15, "	2.01	1.06	.005	"
390,117	" 15, "	2.70	.99	.005	"
368,728	" 15, "	3.31	1.14	.006	"
178,713	Nov. 6, "	5.89	2.23	.007	"

The Blue Wing vein is fairly persistent and can be traced by outcrop or by quartz débris on the surface with some interruptions for nearly half a mile. Just how much of it throughout this distance is mineralized is not known, but at least three openings at intervals of more than 1,000 feet show ore. These are the Blue Wing mine proper, the opening 1,000 feet to the south known as the Spring shaft, and an abandoned pit 25 or 30 feet deep about one-fourth mile south of the Spring shaft. Some of the surface débris between the Spring shaft and this pit shows copper stains, and it is not improbable that more prospecting would develop other more promising ore shoots. Of the four ore shoots thus far known, the two at the main shaft are most promising. The one at the Spring shaft shows good ore as far as development, which consists only of a shaft about 100 feet deep, has gone. While the average ore at this shaft does not contain as high a percentage of copper as that at the main shaft, all geological conditions, so far as could be determined, are similar, and it is not improbable that future work would develop an important body of ore at this place. This shaft was filled with water at the time of the field work and was,

therefore, not accessible for study, and the statements in regard to it are, therefore, based on an examination of the material on the dump and on reports of men who worked in the place. At the opening, about one-fourth mile south of this shaft, the conditions are somewhat different. So far as could be determined from the abandoned and caved pit, the vein is well defined but narrower, and, judging by material on the dump, contains very little calcite. The ore also differs from that at the Blue Wing and Spring shafts in that it contains specular hematite in excess of the copper-bearing sulphides. Bornite and chalcocite are present, but in all the material available for examination were found to be subordinate in amount to the hematite. Hematite occurs with the sulphides in all the mines of the

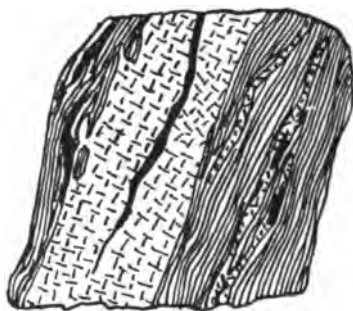


Fig. 8.—Blue Wing vein at the south face of the 100-foot level. On the right is schist carrying streaks of quartz. In the middle are barren quartz and calcite with a band of ore in the center. On the left is schist containing quartz lenses and ore. (After W. H. Weed.)

district, but only in this one prospect is it present in great abundance. Its relation to ore and gangue minerals, so far as noted, is the same in all cases, that is, intergrown and contemporaneous with them.

Only at the Blue Wing shaft has development work gone far enough to afford data on the pitch and other characteristics of the ore shoots, and even in this instance it is not extensive enough to warrant much in the way of generalization. It can be stated, however, that the ore does occur in definite ore shoots in which it shows a tendency to be segregated largely in different places in the vein, but that this segregation is in no place complete, and that smaller but important amounts of ore are distributed irregularly through the vein. It may also be stated that, so far as development has gone, the ore shoots have a pitch in the vein of about 65 degrees to the south, having, therefore, approximately the same pitch as the diabase dike which intersects the vein in this mine.

Production.—No record of the total amount of ore taken from this mine is available, but, judging from the amount of stoping that has been done and from such records as could be found, it would certainly not be placed below fifty thousand tons. It is also believed, from an examination of such smelter returns as were accessible, that the ore taken out and shipped carried an average of about 4 per cent of copper.

Future of the mine.—The part of the geologist's report on a mine which is probably of greatest interest to the owners of the mine and those interested in its development are his statements in regard to the possibilities and probabilities of the future development of ore in the mine. This, indeed, is the very part of his report that he would most gladly omit if he felt that he could do so without shirking his duty.

It is believed that the studies of the Blue Wing mine will warrant a few surmises as to its future. It is commonly stated that the only way to judge the future is by the past, and this method will be used in making statements as to the future of this mine. The geological conditions are practically the same in the vein as it is opened by the deepest level and at the bottom of the shaft as they are on the first level. To be sure, there are irregularities and variations in the amount and distribution of the ore from place to place, but as regards the really important features, such as the size and persistence of the vein, the mineralization, and the continuation of the ore shoots, etc., the conditions are practically the same in the deepest workings as they are at the first level. The vein is clearly a fissure vein, and this type of vein is always counted upon to carry good values to great depths. The value of the ore thus far taken out was in all probability not much increased by processes of secondary enrichment, and it is believed to represent values practically as they were originally deposited in the vein. Taking all these data into consideration it is assumed that one is justified in believing that the ore which has been developed up to the present time may be regarded as an example of what future development may show. It is, therefore, believed that development work should be continued with the expectation that the ore shoots will hold their value in depth, and that further ore, comparable with that already developed and taken out, will be found.

In regard to the future of this mine, Mr. J. Parke Channing, in a commercial report, stated:

"The Blue Wing mine has not been tested north and south with drifts, and it is quite probable that further development in these directions would

show other ore bodies. From the results of the various samples I am of the opinion that this mine will produce ore carrying 2 per cent copper and 8 ounces of silver with a silica excess of about 60 per cent. I assume that the mine can produce 20,000 tons of ore per annum and I am of the opinion that the cost of development will be about 65 cents per ton and that the total cost of mining, including development, will be two dollars per ton."

HOLLOWAY MINE.

General statement.—The Holloway mine is located about 3 miles south and 1 mile west of the town of Virgilina, and a short distance east of the county road leading south from the town. The wagon roads connecting the mine with Virgilina are in only fair condition, but they are so located that a small amount of work would improve them greatly. The mine is connected with the Southern Railway at Virgilina by a branch line which runs from the mine to the junction about 1 mile east of the town, thus giving good shipping facilities.

There is not a sufficient supply of water immediately at hand for carrying on extensive operations in ore dressing if such should ever be desirable. However, about 1 mile west of the mine is Crooked Creek, and approximately 2 miles east is Aaron's Creek, and, by impounding either stream at the nearest point to the mine, ample water can be obtained and supplied to the mine by pumping. The timber conditions surrounding the Holloway mine are similar in all respects to those at the Blue Wing mine. Thus there is available an ample supply of both oak and pine timber for all mining purposes.

The land on which the Holloway mine is located formerly belonged to William S. Holloway, who used it for farming purposes, and who, in 1880, while plowing, discovered the first indications of copper which consisted of the green and the blue carbonates. Mr. Holloway was somewhat interested in the copper stains and sunk a test pit to a depth of 15 or 20 feet, exposing promising rock. In 1884 the prospect was purchased by Judge A. W. Graham, of Oxford, N. C., who had a small amount of development work done and sold it in 1885 to parties by the name of McPherson and Heitman. These men started work on the quartz vein about 100 feet west of the present main Holloway shaft. They apparently did not have sufficient funds to carry on the development of the property and it was soon sold to satisfy debts incurred in the prospecting, and was purchased by W. H. Ragan, of Mocksville, N. C., and E. L. Gaither, of High Point, N. C. They did little or nothing to develop the property, and in the latter part of

1887 sold it to William M. Pannebaker, of Lewistown, Pa. Mr. Pannebaker did a small amount of prospecting, but nothing in the way of important development, and in the early part of the year 1897 sold one-half interest in the property to W. E. C. Eustis, of Boston, and leased the other half to him on a royalty basis. With this transaction the actual development of the mine began. The work was carried on actively, and it is reported that during 1899 and 1900 about 120 men were employed in and around the mine, and that the work was carried on in two shifts of 10 hours each.

In May, 1901, mining had reached to a depth of 440 feet. During October, 1901, work on these lower levels had ceased, but work was continued on the upper levels and ore was shipped until March, 1903.

In 1903 Mr. Eustis made a proposition for individual ownership of the mine to Mr. Pannebaker, by which Mr. Pannebaker finally obtained control, and in November, 1916, the mine was in possession of Mr. Pannebaker's estate, he having died in 1914. In 1905 Philadelphia parties, backed by Harrisburg politicians, became interested in the property and partially reopened the mine, retimbering shaft No. 1 to a depth of 115 feet. At this point the famous Harrisburg Capital troubles arose, the backing failed, and the work was discontinued, it is said, much against the recommendation and wishes of the persons actually in charge of the work. As a result of cutting the walls to accommodate the new timbers about 6 tons of ore assaying 8.64 per cent copper were obtained and shipped. No further work on the property has been attempted and the mine has remained closed and filled with water to the present date.

The dump of low-grade ore that accumulated during mining began to be worked over just as soon as the Eustis smelter at Norfolk, Va., was completed; and as early as December, 1899, material was shipped from these dumps to the smelter, as it was needed as a flux. Later, in 1909 and 1910, the remainder of the dump was purchased by R. G. Lassiter and shipped for use as macadam and railroad ballast.

Development.—Judging from the general appearance of the mine during the time of the field work for this report, nothing was done in the way of surface development or improvement that was not absolutely necessary in order to get out the ore and ship it. In fact, it appears that in all the work only the cheapest and poorest grade of material was used, and that this was put together in the cheapest way possible. The shaft was not housed nor properly timbered, and it is reported that not even the absolutely necessary timbering was done in the mine. At present, all that remains of such

surface plant as was put up is the railroad track, a rickety old boiler house, and a dilapidated boiler.

Taking into consideration all available data, the surface development seems to have been characteristic of the underground work. Judging from such observations as could be made and from reports of many men who worked in the mine, the object sought by the management seems to have been to take out the ore in sight just as cheaply as possible. Apparently no development work was done looking toward extending the mine, or

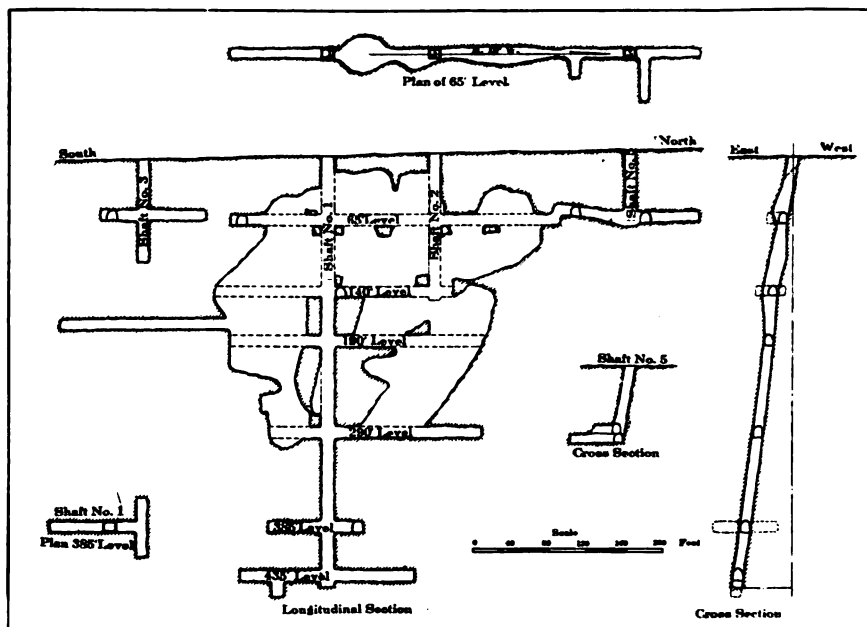


Fig. 9.—Vertical sections and plans of Holloway mine. From map made from notes by J. D. Battershill, 1903.

toward developing a future supply of ore. A single large lens of rich ore was in sight, and the object of the management appears to have been to get this out as quickly as possible. Five shafts were sunk on the property. Of these only No. 1, which is the main working shaft, was sunk to any important depth. The shaft is about 450 feet deep, and from it six levels have been broken off at 60, 140, 200, 290, 385, and 435 feet from the surface, respectively. It is an inclined shaft and follows approximately the dip of the schists, which is 70 to 80 degrees to the east. The total drifting,

all of which, except a very small amount, was necessary in getting out the lens of ore, amounts to about 1,800 feet. Practically all of the drifting was done in the vein. The mine was under water at the time of the field work and was, therefore, not accessible for study. However, such data as were available were collected, and the vertical section given on page 116 was made from a sketch of the workings by J. D. Battershill, who was superintendent of the mine throughout the whole period of its operation, and is reasonably correct. These data show that there was an irregular ore body about 300 feet long and varying from 3 to more than 100 feet in width, which has been stoped out for a width varying from 3 to 33 feet. This stoping extends from within about 30 feet of the surface to the 290-foot level. Weed^a reports in 1900 that the mine was hoisting from 30 to 40 tons of ore per day, and states that this ore was cobbled and picked by hand and that from it 16 to 20 tons of ore were selected per day for shipment.

Geologic relations.—The rock in the Holloway mine is the typical Virgilina greenstone; both the tuffaceous and the porphyritic phases being represented. No rock is exposed at the surface in the immediate vicinity of the mine, but judging from the rock hoisted in mining the ore it is somewhat more massive and contains more epidote than the average greenstone. However, it has suffered intense dynamic metamorphism and is decidedly schistose but not to the extent of completely obliterating its original characteristics. The strike of the schistosity varies in the vicinity of the mine from 20 to 35 degrees east of north, and the dip is uniformly from 70 to 80 degrees toward the southeast.

There are two veins or mineralized fissures on the property, one, the principal vein, has a trend of approximately 15 degrees west of north, while the other, apparently not so strongly mineralized as the first, has a trend of about 5 degrees east of north, thus crossing the first vein at an acute angle. The trend of the second vein is marked by considerable quartz débris, while the first has very little in the way of surface outcrop. Little is known as to the strength of mineralization in the second vein. One shaft has been put down on it to a depth of about 80 feet, and it is reported that it produced shipping ore. This shaft was partially caved and filled with water at the time of the field work for this report and nothing as to the character of the vein could be learned from actual observation.

The principal vein, as has just been stated, is not at all well marked at the surface; in fact, there is little or no outcrop. It is clearly of the fissure

^a Loc. cit.

type and was developed in a fracture or fissure which in trend cuts the schistosity of the country rock at an angle of about 45 degrees and which dips about 80 degrees toward the east. All the openings on this vein were filled with water at the time of the field work for this report and consequently were not accessible for study. The following account of the geology of the mine is taken from data which the writer believes to be reliable. It comes almost wholly from two sources, a report on the Virgilina district by Weed,^a and notes and other data on the mine compiled by Miss M. Florence Pannebaker from records and reports of the mine while it was being operated under the Eustis lease, and by her kindly placed at the disposal of the writer.



Fig. 10.—Sketch showing face of 300-foot level, south, in Holloway mine, January 26, 1900. On the left, black quartzose ore; in the center, white quartz stringers in black gangue. (After Weed.)

It appears from Miss Pannebaker's data that, in sinking shaft No. 1, the main shaft, at a depth of about 14 feet a thick mud seam was encountered beneath which was rich chalcocite ore. At 18 feet the vein was 13 feet wide with a pay streak of chalcocite ore between 2 and 4 feet wide and assaying as high as 44 per cent copper. It is also stated that, from the surface down to, and considerably below, this depth, the entire contents of the shaft averaged over 3 per cent copper, much of which occurred in the form of the green and the blue carbonates. Some shipments were made from material obtained in the sinking carrying as high as 33 per cent copper, with a number of carloads of 10 per cent average. At a depth of 112 feet, while the full width of the vein was not known, the 6 feet included in the width of the shaft averaged from 8 to 10 per cent copper. The records show that during the first year of work, spent largely in sinking

^a Weed, Walter H.: Types of copper deposits in the Southern United States. Trans. Am. Inst. Min. Eng., 1900, Vol. 30, pp. 449-504.

YEAR	
1897	
1898	
1899	4
1900	6 6
1901	2 2
1902	1
1903	4 2

and drifting, there were shipped, in all, 89 cars of ore which averaged 11 per cent copper with some shipments running as high as 40 per cent.

Miss Pannebaker's records furthermore show that, so far as removed from the mine, the richest ore occurred roughly in two shoots, one a short distance south and the other about 120 feet north of the main shaft, near shaft No. 2, and that both shoots had a pitch in the vein approximating 70 degrees toward the south. The ore in both shoots was of uniformly high grade and in both the vein was very wide. According to Weed the south shoot was 33 feet wide on the first level, 75 feet below the surface south of the shaft. Other records show that this shoot farther down was stoped to widths varying from 15 to 30 feet or more. The north shoot was also of high grade ore, but was probably not stoped quite so wide as that in the south shoot where the reports mention stopes up to 30 feet in width. Between these two large shoots the vein was narrower, from 3 to 10 feet, but well mineralized. Nothing in the way of stoping was done below the fourth level although the vein was well mineralized and material removed in sinking and drifting was shipped to the smelter. The records also show that in the shaft at a depth of about 440 feet a body of very rich ore was encountered. Records of shipments made at the time this sinking and drifting were in progress and presumably from this work show an average of 9.11 per cent copper. It was reported that the drift and cross-cut on the fifth level, north, were mineralized for a width of about 60 feet and that in the drift on the sixth level, both north and south, shipping ore was obtained.

Records which might show the character of the ore produced by this mine are scarce and difficult of access, and there were no geological examinations of the ore body while the characteristic high-grade ore was being taken out. At the time of Mr. Weed's report the greater part of such ore of this type as had been developed had been removed, and much of the mine was not accessible for examination. There are also many conflicting reports regarding the mine which are generously poured into the ears of any one who, for any reason, manifests interest in the possibility of the mine again becoming a producer, oftentimes much to the injury of the mine and of the district as a whole. Because of all this and in order to render accessible such reliable information on the subject as exists, it was decided to include the following table of settlement returns on representative shipments of ore from the mine during the years 1897 to 1903. The table by no means includes all the shipments made during the period covered, but it is believed that such as are included are representative and that they

furnish a reliable basis on which may be formed an estimate of the grade and character of ore produced by the mine. The table was compiled by Miss Pannebaker from actual smelter returns in her possession and by her placed at the writer's disposal.

The vein has been prospected and more or less developed for a distance of about 800 feet, and it is reported that each of the prospect shafts showed more or less ore, and that shipping ore was taken out of both the northernmost and the southernmost developments.

The following is Weed's^a account of this mine which, in the main, corroborates the data furnished by Miss Pannebaker:

"The vein varies greatly in width, showing the lenticular structure noticed on a small scale in the railroad cut, and, in fact, repeated in the ore-body itself. It varies from 3 feet to 75 feet, or more, in width. In general, there is a fairly defined foot-wall, showing a dip of 75 degrees. The hanging-wall is less defined; and both foot and hanging show irregularities, due doubtless to the crossing of the schists by the vein at a slight angle, and the presence of projections where the rocks are slightly harder than the usual schists. It should be remarked also that the course of the Holloway vein, north 15 to 20 degrees east, is not that of most of the veins of the district.^b

"In the lower or third level of the mine, the vein is 12 feet wide at the south face, and shows white and gray quartz, with epidote and gray chalcocite 2.5 feet wide. Fig. 10 represents a sketch made in the mine at this level. Here the hanging-wall is rolling, and there is no defined foot-wall. It is also noticed that the quartz sends little droppers or feeders into the schists, in stringers parallel to the schistosity. This is illustrated in Fig. 11.

"On the third level, south of the shaft, the vein was lost in following the foot-wall, so that there is a short cross-cut into the country-rock. Fig. 12 shows the cross-section of the ore body on this level, to the south. In general, it is noticed that the vein south of the shaft is well-defined, and has good walls up to the first level. The quartz is cased in a soft, micaceous slate, which is not a gouge or selvage in the ordinary sense, and may be a schist forming part of the country rock. . . . On the third level, the vein pinches toward the shaft to about 3 feet, and continues with this width to the shaft and northward for a short distance, beyond which it widens to 6 or 8 feet in width. North of the shaft, the vein is broken by an inclined fault-plane, marked by a mud containing sharp angular fragments of ore and quartz, and dipping east about 30 degrees. It does not throw the vein, though it shatters the walls.

^a Loc. cit., pp. 458-461.

^b The author states the course of the vein is north 15 to 20 degrees east which, since by actual survey the trend is north 15 to 20 degrees west, must be a typographical error.

"The ore-body in the third level is altered along cracks showing films of green carbonates in both the ore and the white quartz. In the bottom of the shaft, however, no decomposition was observed. A prospect-drift, which has been started about 25 feet above the face of the third level, shows a black jaspery rock, with crossings of white quartz. There is no ore exposed except on the north wall, where there is a slight green stain.

"On the second level south no timbering exists, so that it was not carloads [of ore] have been shipped from this mine, which varied from shows hard, finely laminated micaceous schists, the schistosity of which makes an angle of about 30 degrees with the vein. At the north end of this level the vein shows a slaty hanging-wall, with quartz feeders running off into it. These feeders wedge off in a few feet, and usually carry ore. The quartz ore-body does not show any marked breccia; but in this, as in all the mines of the district, there are the usual thin, plated masses of decomposed schist. In general, the richer ore is found near the foot-wall. No definite association was observed between the occurrence of ore and the character of the various schists cut by the vein.

"On the first level, 75 feet below the surface, south of the shaft, the vein is 133^a feet wide, but converges rapidly in both directions."

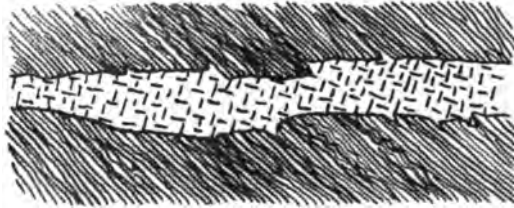


Fig. 11.—Ideal horizontal cross-section of the Holloway vein, showing quartz spurs following the foliation of the country schist. (After Weed.)

Mineralogy.—The gangue minerals, exclusive of fragments and bands of country rock included in the vein, named in the order of their abundance, are: Quartz, epidote, chlorite, hematite, and a little pink feldspar, probably orthoclase. The ore minerals in the order of their abundance are: Chalcocite, bornite, malachite, azurite, and argentite (?). cuprite, native copper, and native silver. All the minerals of the vein, except the oxidization products and a part of the chalcocite in the upper portion of the vein, which is clearly secondary, are intimately and complexly intergrown and are believed to be of contemporaneous development. Epidote occurs in this mine in greater abundance as a gangue mineral than in any other mine or prospect in the district, and calcite is probably a little less abundant than

^a This should read 33 feet. See Weed, Copper Hand Book, 1916, p. 591.

in the other mines. Chlorite is plentifully present, and was probably derived from the country rock and perhaps represents altered fragments of the greenstone. Feldspar, both orthoclase and plagioclase, is sparingly present and was found in a few specimens of gangue matter on the dump. So far as was determined, the ore minerals are associated very intimately with the gangue minerals and are pretty well distributed throughout the vein. However, there is a decided tendency toward a segregation of the ore at different irregular places throughout the vein. Chalcocite is by far the most abundant ore mineral and probably represents a greater percentage of the ore than in any other mine in the district. Excepting that portion of this mineral in the upper workings of the mine, it is probably all, or practically all, hypogene or primary deposition and is believed to be contemporaneous with the bornite. Bornite and chalcocite are intergrown in the ore of this mine in much the same manner as was noted in the Blue Wing mine. However, no well-defined graphic intergrowths, such as those in the ore from the Wall mine, were noted. The general appearance of the polished section under the microscope suggests an intricately branching mass of bornite merged with a similar mass of chalcocite, the latter mineral predominating. Malachite is the more abundant of the two carbonates. In fact, azurite occurs only sparingly. They are confined to the upper portion of the vein, extending, however, in one instance near the fault plain mentioned by Weed, to a depth of 300 feet. Hematite, while widely distributed, is by no means an abundant mineral. It is not known in what form the silver occurs, but it is believed to be present as argentite. Cuprite occurs sparingly in the oxidized portions of the vein. Native copper and native silver are said to have been found as films in fractures in the oxidized portion of the vein.

Two connected shoots were partially proven, but the work in them was not sufficient to afford data for much in the way of generalization. As opened up by the workings, the ore shoots taken together are about 300 feet long in their greatest linear extension, from 5 or 6 to about 100 feet in width, and extend to a depth of at least 450 feet from the surface. Like the other ore shoots of the district, they appear to have a slight pitch to the south. The ore, while largely segregated in various portions of the vein, is also irregularly disseminated through it so that very little of the vein in the ore shoot is wholly barren. It is believed, however, from such data as were available, that segregation of the values was more nearly complete in this than in the other ore deposits of the district, and thus it was that

the operators were enabled to select a relatively greater amount of high-grade ore than was possible in the other mines that have been worked.

Whether or not there are other ore shoots in the Holloway vein is not known, since no development work of any importance has been done except in the two ore shoots already mentioned. It is, however, unlikely that there should have been only one ore shoot developed in such a strong vein and further prospecting along its strike would certainly be justified.

Production.—There were no means of ascertaining the total output of ore from the Holloway mine, but it is reported that in value, the ore taken out was worth considerably over \$500,000. Weed says that at the time of his visit, in 1899, the mine was shipping from 18 to 20 tons of ore per day. Assuming that this production was maintained for 200 days during each



Fig. 12.—Sketch showing cross-section of the Holloway vein as seen in the 300-foot level, south. (After Weed.)

of the five years the mine was in operation, the total production would then be 180,000 tons, which figure, however, is probably in excess of the actual production. There were but little data available as to the distribution of the values in the ore shoot, but it is believed that, taking it as a whole, it ran considerably higher in copper than the other ore shoots of the district. Judging from such smelter returns as were accessible, it appears that the silver and gold content were slightly higher than in the majority of the mines and prospects of the district. In some portions of the ore shoot the ore consisted of nearly pure sulphides and carried a very high copper content, it being known from smelter returns that hand-picked ore running as high as 40 per cent copper was shipped in carloads. Weed states that in 1899 the mine yielded about 61 tons of ore of two grades, the first averaging 30 per cent or more of copper and the second over 12 per cent. It is quite

evident that these statements do not take into account the lower grade of ore and the fines all of which were discarded at that time. These, however, were shipped later and smelter returns for more than 50 carloads of them show a copper content of a little less than 3 per cent. The following table showing the production of the mine, which by no means is complete, was compiled by Miss Pannebaker from actual settlement records in her possession.

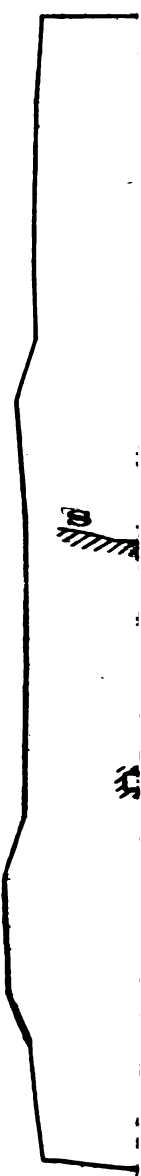
240 cars shipped prior to January 27, 1900, which
averaged over 10% copper.
16,157 tons shipped which averaged over 6% copper.
10,000 tons shipped which averaged over 8% copper.
6,000 tons shipped which averaged over 3% copper.
3,185 tons shipped which averaged under 2% copper.

Future of the mine.—Taking into consideration the character of the work done at this mine and the size and importance of the ore body, it is believed that further and extensive exploratory work should by all means be undertaken. The shaft should be sunk until it passes out of the ore shoot, and further development drifts should be driven both north and south in the vein. It also should be borne in mind that the vein crosses the schistosity of the country rock; that it shows a tendency to send off feeders or stringers of ore parallel with the schistosity; that it has an irregular contour; and that its walls are "billowy" and in some instances not well defined, and a system of regular cross-cutting should be carried on in connection with the drifting. If the study of this mine has made a single point clear, it is that the ore deposit has certainly not been prospected to the extent that its size and importance would warrant. It is, therefore, believed that further development can be undertaken with a reasonable hope of finding valuable ore. As the Holloway mine stands to-day, the author regards it as one of the most promising prospects in the Virginia district.

HIGH HILL MINE.

General statement.—The High Hill mine is located about 9 miles north of Virginia from which it is reached by a fair wagon road. There are no railroad facilities and Virginia is the nearest shipping point. The location of the mine is such that in case it should ever be developed to an extent that would justify it, a branch could be extended from the first siding on the Southern Railway west of Virginia, along a ridge to High Hill at a minimum expense, which would pass the Wall and Seaboard mines and a number of favorable prospects including the Littlejohn and the Elliot.

The timber lands surrounding the mine have been closely cut over, but there is yet a supply of both oak and pine ample for all needs in operating



the mine. At the time of the field work an abundance of cord wood could be obtained for fuel, delivered at the mine for one dollar per cord.

Unfortunately, the mine has no immediate water supply. The water used for mining and milling purposes in excess of that made by the mine, which is very little, is obtained by pumping from Hyco River, about one-half mile northwest of the mine. When the mine and mill were in operation a pumping station consisting of boiler, 50 h. p. engine, and 18 by 9 by 12 duplex pump, and a 6-inch pipe line to the mine, were installed at a point on the river about 2,800 feet from the mine. This supplied all the water necessary in the operations.

The mine is located near the north end of a prominent ridge which extends southward toward Virgilina and attains its maximum elevation at the mine of about 200 feet above the river level.

Actual development of this mine began in 1899 and was brought about largely through the activities of Judge A. W. Graham, of Oxford, N. C., and W. T. Harris, of Virgilina, Va., who interested, Boston, Mass., capitalists in the property. Prospecting proceeded rather rapidly and in December, 1899, 14 pits and shafts varying in depth from 25 to 125 feet had been sunk in the vein. These were numbered from 1 to 14, consecutively, beginning at the north, and were so spaced as to prospect nearly 1 mile of the vein.

None of this early work except the upper part of some of the pits was accessible at the time of the field work. Taking into consideration the lack of system in the later development of the mine and the fact that none of the work is accessible at the present time it is thought best to include a few paragraphs from a commercial report by H. F. Wild, a mining engineer, who examined the property in December, 1899. In describing this development work Mr. Wild says:

"Shaft No. 4 is 125 feet deep and Nos. 1, 2, 3, 5, 6, 7, and 8 are more than 50 feet deep, No. 2 being 93 feet. At the bottom of No. 1 shaft there is a drift on the vein 180 feet to the north and 130 feet to the south connecting with and extending beyond shaft No. 2. At the 60-foot level in shaft No. 4 there is a drift 100 feet long and a stope 31 feet long and 16 feet high. To the south of the shaft is a drift 15 feet long and at the 96-foot level a drift 15 feet long. At the bottom of shaft No. 8 are two drifts on the vein each 9 feet long. This shaft is 72 feet deep. None of the various shafts has been sunk at the points which at the surface show the largest croppings of quartz, and as depth is attained the ore has increased in width and value. Surface leaching has depleted the values for some 15 or 20 feet beneath. Then the percentage of copper increases. In

drifts from No. 1 shaft the ground to the north has been stoped out and at the extreme north the drift is within a few feet of the surface (owing to the contour of the hill). The ore shows for the entire length of the drifts (in the bottom where stoped above and in roof, bottom, and elsewhere), varying from 2 to 5 feet in width, averaging about 3 feet. In shafts Nos. 1 and 2 the vein shows about the same as in the drifts down to their level and in No. 2 below the drift the vein is very wide, but as the shaft has been sunk in the foot-wall side of the vein the streak of rich ore has not been exposed. The No. 4 shaft and the drifts from it are in the foot-wall side of the vein and are all in ore, the wall on the hanging side not having been reached except at one point in the shaft where a cross-cut shows the vein to be 14 feet wide. The shaft itself is 9 feet wide and a drill hole at the bottom shows the quartz to be at least 11 feet wide. In the drifts from this shaft the ore averages over 6 feet as exposed and since the hanging wall has not been reached the real width is greater. At the bottom of No. 8 shaft the vein has pinched to about 1 foot in width, but in the drifts from the bottom, although they are only 9 feet long, it has widened out to two and one-half feet. The streak of rich ore in the quartz vein varies in extent, not always corresponding with the variations of the vein itself and occasionally it occurs in kidneys through the quartz, but I estimate from my measurement and from the proportion it forms of the ore already extracted, that the rich ore forms about one-sixth of the entire contents of the vein."

Shortly after Mr. Wild's report was made the mine was taken over by its present owners, a stock company known as the Virginia Copper Company, Ltd. This company was organized under the laws of Great Britain, but maintained, during the operation of the mine, an office in New York City. Development work was continued largely, however, at shafts Nos. 3 and 4, which were chosen as the main working shafts. These were sunk to depths of about 250 and 350 feet, respectively. Two levels were broken off from shaft No. 3, and 3 levels from No. 4. From these levels stoping was done as shown in the vertical section of this mine on page 124. This stoping was evidently very carelessly done and the shattered ground was not properly timbered, and, as a result, nearly 300 feet of ground above the first level south of the shaft caved.

Good buildings, such as shaft house, boiler and power house, office, shop, a residence for the manager, and some houses for laborers, were erected. The shaft was equipped with good machinery including hoisting engine and a 20-drill air compressor. Later, in 1901, a mill was erected and an attempt was made to concentrate the ores. So far as could be learned the equipment was very inadequate and not suited to the ore. At any rate the work was a significant failure. The equipment consisted of a rock

breaker, some screens, a picking belt, and a set of Harz jigs. The rock breaker was the only crushing machinery employed and all material too coarse for the jigs was screened out and discarded. As a result there is now at the mine a large dump of this discarded material, which, according to assays, will run nearly 2 per cent in copper. The work continued in a somewhat desultory way until the price of copper reached a very low figure when the mine was closed. In 1907 the mine was reopened and another attempt was made to treat the ores. This time the process consisted in giving the ore a sulphating roast in a specially designed furnace. This was followed by an acid leach and it, in turn, by electrolytic precipitation of the copper. An expensive plant was erected and operated only long enough to demonstrate that the method as installed was a failure. The mine was immediately closed and has not been reopened since.

Geologic relations.—The rock of the High Hill mine is the normal schistose Virgilina greenstone. The greater part of it is decidedly schistose, but here and there are areas which show the original tuffaceous character of the rock. Some of the rock is of a dark green color and is fairly massive, while a smaller amount has a decided purplish color.

The High Hill vein is one of the strongest in the Virgilina district and is clearly traceable either by a well-defined quartz reef or abundant quartz débris on the surface for a distance of nearly two miles. The outcrops rise from a few inches to 3 or 4 feet above the surface, and where there is no definite outcrop the surface is literally covered with quartz débris. So far as could be determined throughout this distance the vein varies from 2 or 3 to 12 or 15 feet in width. It is remarkably regular in trend, showing throughout its whole length very slight variations from 6 degrees west of north. The strike of the schistosity is toward the northeast and cuts the trend of the vein at angles varying from 20 to 30 degrees. These facts make it clear that this is a true fissure vein developed in a fracture formed subsequent to the metamorphism of the country rock. In this respect it is similar to the other veins of the district. Like the other veins it also presents both vertical and longitudinal pinches and swells. It appears to contain a larger percentage of quartz, and is, therefore, more highly siliceous than any other vein in the district, with the possible exception of the Durgy vein which carries an approximately equal percentage. It carries less epidote than the Seaboard and Holloway veins and less calcite than the Blue Wing. So far as could be determined both foot and hanging walls are well defined and the vein parts easily from them. In this as in all other

veins of the district there are numerous inclusions of plates or layers of country rock which, in places, give it a laminated or banded appearance.

The gangue minerals, exclusive of fragments of country rock, included within the vein, named in the order of their abundance, are: Quartz, epidote, chlorite, calcite, and hematite. The ore minerals in the order of their abundance are: Bornite, chalcocite, malachite, azurite, covellite, and argentite(?). Ore and gangue minerals are intimately intergrown and there is little doubt that they were deposited contemporaneously. In this, as in the other mines of the district, there is a decided tendency on the part of the ore to occur as segregated areas or masses throughout the vein.

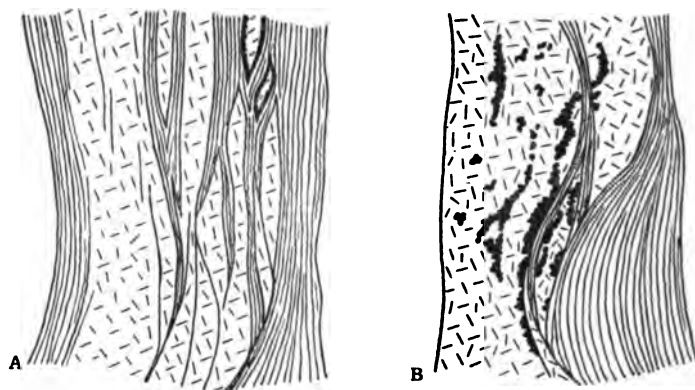


Fig. 14.—(A) High Hill vein at Shaft No. 4. North face of 60-foot level. Vein eight to nine feet wide. Ore is shown in solid black. (After W. H. Weed.)

(B) High Hill vein, north face at bottom of Shaft No. 4, as it appeared January 28, 1900. Vein from eight to nine feet wide. Ore is shown in solid black. (After W. H. Weed.)

This tendency, however, has not been carried out completely, so that no part of the ore shoot is wholly barren. The bunching of the ore is not confined regularly to any portion of the vein, but occurs in some instances near the foot-wall, in others near the hanging wall, and in still others near the center of the vein. From such data as were available at the time of the field work the run-of-mine ore from the mine will carry an excess of silica varying from 70 to 75 per cent.

As far as could be determined from the development work accessible and from such data as were available, the values occur in definite ore shoots which are believed to have a slight southerly pitch in the vein. At least three such ore shoots have been developed to a greater or less extent at shafts Nos. 2, 3, 4, and 8, respectively, but the development has not been

sufficient to furnish data for accurate statements as to their respective size. Dealing with this subject in a commercial report on this mine, made after a detailed examination of the property, J. Parke Channing says:

"It is extremely difficult to determine the length of the shoots developed, but I should say that shafts 3 and 4 would probably produce 1,000 feet of pay ground, shaft No. 8, 150 feet, and shaft No. 2, 200 feet, or a total of 1,350 feet."

In addition to this amount of pay ground which is already partially developed, the prospect pits and copper stainings in the outcroppings of the vein indicate that further development of the property will probably disclose other valuable ore shoots. But few data on the copper and silver content of the ore were available, but such as could be found indicate that a considerable quantity of high-grade ore was taken out and shipped. H. F. Wild states, in his report above referred to, that as a result of the earlier work at the mine ore as follows was taken out and shipped:

Lbs. Sampled	Cu. Per cent	Ag. Ozs.	Au. Ozs.
46 365	27.83	6.00	0.02
46,310	7.60	0.40	0.01
51,977	8.40	1.90	0.01
40,273	15.11	n. d.	n. d.
40,092	17.30	n. d.	n. d.
42,493	13.95	n. d.	n. d.
50,023	33.76	8.46	0.22
145,052	16.40	4.37	0.03
2,000,000 (estimate)	1.72	1.22	0.02
400,000 (estimate)	2.85	0.90	Trace

Production.—After considering the figures just given, H. A. Keller, in a commercial report on this property made in September, 1905, says:

"The total shipments of ore from this property amounted to approximately 1,414 tons (ore and concentrates), which contained an average of approximately 12.2 per cent copper with corresponding silver values. There are now on the dumps, mill tailings, and low-grade ore thrown out from the mill 8,600 tons (estimated) divided about evenly between the two. The latter goes about 2 per cent copper and the former a little over 1 per cent (according to numerous samplings and assays). Therefore there have been taken from the mine 10,014 tons of ore, which shows an average (by approximation) of a small fraction over 3 per cent copper with corresponding silver values."

Future of the mine.—The development of this vein certainly has not been extensive enough to either prove or disprove its value. So far as it has gone it shows favorable conditions. The vein is large, very persistent, and, so far as explored, reasonably well mineralized. Taking into consideration the geologic conditions of this vein, it is believed that further development work ought to be done, and that it may be undertaken with reasonable hope of success.

DURGY (PERSON CONSOLIDATED) MINE.

General statement.—The Durgy mine is located about 7 miles southwest of Virgilina. The wagon road connecting the mine with the town is kept in good condition. The nearest railroad point is the Holloway mine, which is reached by a branch track from the Southern Railway at Virgilina. This station is about 4 miles from the mine, but the wagon road is in good condition. The last hauling from the mine (in 1910) was done by a steam traction engine and heavy trucks. Well-built modern motor trucks could, at reasonable expense, easily take care of all hauling to and from the mine. There is no immediate water supply and the water needed in the operation of the mine and mill is obtained by pumping from an impounded stream about one-half mile west of the mine. Except during the driest seasons this supply is ample.

Timber has been pretty well cut off from the territory adjoining the mine, but the surrounding country is still well timbered with both oak and pine, so that there is an ample supply of timber and lumber for all mining purposes.

The land on which the Durgy mine is located was, at the time copper was discovered, the property of Theron Yancey, and the first exploratory work was done by him and under his directions. This was one of the early mines of the district and was in active operation in 1892. The vein at the places where the first shafts were sunk did not outcrop, but its presence was made known by an abundance of quartz débris on the surface. It is said that the stains of malachite in some of this material turned up in plowing were responsible for the prospecting which led to the discovery of the rich ore, consisting largely of chalcocite, and to the opening of the mine. During this early work one shaft was sunk to a depth of 150 feet and another to 88 feet. The work showed good values in the vein and it is reported that considerable ore was taken out. The mine at this time was fairly well equipped and the shaft was well timbered. A concentrating plant was erected on a small stream about five-eighths of a mile west of

the mine, and cabins and houses were built for the miners. With things in this condition the company failed, due, it is said, not to lack of ore, but to mismanagement. At the time it was known as the Yancey mine. The mine was allowed to fill with water and remained idle until 1899 or 1900, when it was purchased by a company of New Haven, Conn., men who organized the Person Consolidated Copper and Gold Mines Company. The organizers and promoters of the company, and, at the time of its organization, the owners of the property, were Fordyce Durgy and E. B. Beecher, both of New Haven.

With the organization of this company the active development of the mine began. Considerable prospecting was done on the different veins on the property and a new shaft—the present working shaft of the mine—was sunk on the main vein, and another on the so-called “Durgy vein” about 1,500 feet northeast of the main shaft was sunk to a depth of about 100 feet. A one-hundred-ton concentrating plant, described fully under the subject of “Concentration,” was erected, and the mine was equipped with modern machinery, air compressor, air drills, good hoisting engine, etc. Work was continued, actively at first, but later on in a desultory way, until 1908, when the mine was closed, but not allowed to fill with water. During this work little attempt was made to keep development work ahead of actual stoping, and, as a result, when hoisting was stopped, little or no developed ore remained in the mine, although vein conditions were favorable. Just before closing the mine the company apparently saw the folly of this policy and sunk the shaft 90 feet deeper and started some drifts at a depth of 407 feet from the surface. This work showed up favorable conditions, the vein at this depth was strong and fairly well mineralized. The mine remained idle until 1910 when an agreement was made between the owners and the Tennessee Copper Company under which this company began work. The drifts were driven in the vein for about 350 feet in each direction. A considerable amount of ore was opened up in this work and about 100 feet of stoping was done on each side of the shaft. The ore taken out was shipped to the smelter at Copperhill, Tenn., where, because of its high silica content, it was used for converter linings and as siliceous material with the heavy sulphide ores from the Ducktown mines. This work was stopped in 1911 and the mine was allowed to fill with water.

The surface equipment consists of shaft house, power house, machine shop, mill, dwelling house for manager, and small houses for miners. The houses are in good repair, but the mining and milling equipment has been allowed to deteriorate.

If reports as to savings can be believed, the mill as installed and operated at the Durgy mine was not a success. These estimates, some of them based on assays of the ore as fed to mill, and tailings, indicate that, on the average, the mill did not save over 60 to 65 per cent of the values. Just wherein the cause for losses lay can not be said, but it is believed to have been partly in the cumbersome installation, partly in the care and oversight of the machinery, and partly in the inefficient methods of saving the slimes. The tailings show values in two forms: ore not freed from gangue, and ore as very fine particles or slimes; the greater part, however, being in the fine particles.

This mine has been more extensively developed underground than any other mine in the district. The two shafts, one 410 and the other 160 feet deep, make a total of 570 feet of shafting. From these shafts a total of more than 4,000 feet of drifts has been driven in the vein, and in addition a small amount of cross-cutting has been done at different places in the drifts. Practically everything accessible in the main ore shoot above the 335-foot level has been stoped out. A small amount of stoping has also been done on the 407-foot level, the deepest level in this ore shoot. A second ore shoot is indicated in the 155- and the 335-foot levels, respectively, beginning about 500 feet south of the shaft. A small amount of stoping has also been done on these levels in this ore shoot. Immediately south of the shaft the stoped ground is caved from the surface down to the 260-foot level, and much of the area north of the shaft, while not caved, is inaccessible. Timbering was not as well done as it should have been and consisted almost wholly of stulls and lagging.

Air drills and modern equipment were used in driving and stoping, and both overhead and underhand stopes were worked. The ore was in some instances roughly sorted underground and as much waste as possible eliminated before hoisting. The ore after sorting was trammed to the shaft and hoisted in a small skip. From the shaft it was trammed to bins at the mill from which it was drawn as needed.

Geologic relations.—The rock at the Durgy mine is the tuffaceous phase of the Virgilina greenstone with very large fragments, and shows more clearly its volcano-sedimentary character than at any other opening in the region. A great part of it shows the usual and normal green color, but here and there are areas that have a dark purplish color, and in a few instances fairly massive, somewhat porphyritic rock was found. In fact, some of the fragments are decidedly porphyritic in texture. The clastic nature of

this rock is well shown by its general brecciated appearance. The fragments are of different colors, many of them green, and a smaller number show well the purple color above referred to. As a rule all fragments have been mashed until they are decidedly lenticular in shape and somewhat like the "augen" in a gneiss. The rock for the most part is highly schistose with here and there areas somewhat massive. The schistosity strikes about 30 degrees east of north and invariably dips toward the east at angles varying from 70 to 80 degrees. Much of the rock as it lies on the mine dump slacks down to a kind of soft bluish micaceous or chloritic material. The fragments in the brecciated or tuffaceous rock are made up of all the different types and colors of the country rock, and in size vary from less than an inch to more than a foot in diameter. In some instances the large fragments are much epidotized, in others they are porphyritic, and almost invariably have withstood the forces of deformation better than the fine-grained matrix, which probably was originally volcanic ash.

There is in this mine, as in the Blue Wing mine, a prominent diabase dike, but it does not cut the vein as in the other mine. The dike, the width of which is not known and which is not exposed on the surface, forms, in some parts of the mine south of the shaft, a foot-wall of the vein. The dike is clearly younger than the formation of the vein and ore, and, so far as could be determined, has had no influence on them. The dike-rock is solid, hard, tough, and massive, and is intersected by many closely spaced joints which break the mass up into numerous polygonal blocks. When it is exposed to the air there is also a decided tendency to slack or break up into small particles. The dike appears to follow the vein for a short distance and then to pass off into the wall rock.

There are at least four, and probably more, veins on the property of this company which show the presence of copper. These are the so-called main vein on which the only work of importance has been done, the Durgy vein lying a short distance east of the main vein, the "Cross-cut" vein, about one mile southwest of the mine opening, and a small unopened vein a few hundred feet west of the main vein. They are all true fissure veins and in all important respects similar to the veins already described. One of the characteristic features of these veins, also true of the other veins of the district, is the regularity of strike and dip. Whether the vein parallels the strike of the schistosity of the country rock or not it is almost invariably regular and persistent in its trend. The predominant vein material is massive white quartz with which are minor amounts of epidote, calcite, chlorite, and fragments and plates of included schist. The veins are also

notably persistent, and it is not at all uncommon for one to be traceable either by actual outcrop or by well-defined quartz débris, on the surface for a distance of a mile or more. Thus the main vein of this property has been traced, largely by surface débris, for nearly, if not quite, a mile. It is one of the largest and strongest veins in the district, varying in width from 6 to 18 feet or more, and, as opened in the mine, fairly well mineralized. Its strike is 5 degrees west of north, and, while in places parallel with the schistosity, taken as a whole its trend is a few degrees more northerly than that of the schists, thus showing clearly that it was developed in a fracture—possibly a fault plane, since there is no means of telling whether or not there was displacement along the line of fracture. However, like the other veins of the district, this one contains in places as inclusions many plates or laminæ of the schists which give it a kind of banded appearance. It also shows the usual vertical and longitudinal pinches and swells.

The gangue minerals of this vein listed in the order of their abundance are: Quartz, epidote, chlorite, calcite, and hematite. The ore minerals in the same order are: Bornite, chalcocite, malachite, azurite, cuprite, argentite(?), a very little chalcopyrite, klaprothite, and a small amount of gold. The hypogene ore minerals are intimately intergrown with the gangue minerals and are probably of contemporaneous development. The ore occurs in definite ore shoots and in these shows a tendency toward segregation at various places in the vein. In no place, however, is this segregation complete, so that in the ore shoot very little or none of the vein is wholly barren. The location of the bunches or areas of ore is irregular and not confined to any one part or portion of it. In some places the rich ore was found to lie near the foot-wall, in others near the hanging wall, and in still others it occurred at different places within the vein. The tendency toward segregation is well shown by the way the ore came from the mine. Three grades were produced: First, that which formed a shipping ore as it was hoisted; second, that which by hand picking or cobbing, thus concentrating from 5 to 10 into 1, could be made into a shipping ore; and, third, a straight milling ore, this last grade constituting by far the greater part of the ore, probably 75 per cent of the total. In a commercial report on this mine, made by Joseph Hyde Pratt, in 1904, the following statements are made in regard to the character of the ore:

“There is considerable variation in the value of the ore as it is mined, there being three distinct ores: (1) That which makes a shipping ore just as mined; (2) that which by hand cobbing will make a shipping ore; and (3) that which is a milling ore and runs from one to two and one-half

per cent copper, but so scattered through the gangue that there is no possibility of hand cobbing it into a shipping ore. A small amount of the ore of class 1 runs from 8 to 15 per cent copper, from 4 to 11 ounces silver, and from a trace to 0.03 ounces gold per ton. Hand-cobbed ore, which is obtained by concentrating from 4 to 8 into 1, gives a shipping ore containing from 13 to 25 per cent copper, 7 to 11 ounces silver, and 0.03 to 0.05 ounce gold per ton. The milling ore which contains from 1 to 2 and one-half per cent copper is concentrated to a product that runs 20 to 56 per cent copper, 8.7 to 22 ounces silver, and 0.03 to 0.17 ounce gold per ton. . . . There is but a small percentage of shipping ore and it is the milling ore that will determine the value of the mine."

From inspection and carefully study of all available data, for the most part, actual smelter returns on carload shipments of ore and concentrates, on the average copper content of the run-of-mine ore, it appears that these statements of Pratt are essentially correct, and that the average copper content of all ore hoisted has been between two and three per cent.

In this mine as in all others in the district a certain amount of mineralization has taken place in the walls adjoining the vein. In mining it is, therefore, necessary always to keep close watch on the walls at the contact with the veins or values may be left.

The relation of the copper minerals of this mine is similar in all respects to that of the same minerals in the other mines of the district. Excepting a certain amount of supergene or secondary chalcocite in the upper portion of the vein, the sulphides are all believed to be primary vein minerals and of contemporaneous deposition. Bornite, which is the most abundant ore mineral, is intimately intergrown with the chalcocite and similar in all respects to the intergrowths described from the Blue Wing, High Hill, and Seaboard mines. Chalcopyrite is very rarely found, and not only is there no indication whatever that it formed the original copper mineral and that the richer sulphides were derived from it, but there is abundant evidence to show that the bornite and chalcocite are hypogene minerals, and in no way related genetically to the chalcopyrite or any other copper-bearing mineral.

The form in which the silver occurs is not definitely known, but microscopic study of polished sections of the ore indicate pretty clearly that it is present as argentite. The silver value is variable, but is usually from 0.8 to 1 ounce of silver to 2 per cent of copper. It is intimately associated with the copper-bearing sulphides and always concentrates with them. The gold content is so low that there is no way of determining definitely the

manner of its occurrence. It is known to occur in the native state in certain mines in the district and is assumed to occur in that form in this mine.

To give a correct statement of the tenor of the shipping ore and concentrates, so far as is known to the writer, the following table, in which is shown the amount of ore sampled and the assay value in copper, silver, and gold, is inserted. The figures are the actual smelter returns and formed the basis on which the smelters made payment for the ore. Some of the assays were made by Ledoux and Company, New York City, and others by the Eustis Smelting Works, Norfolk, Va. The table covers shipments ranging from 1902 to 1905, and thus shows the character of the ores as they occurred throughout a good portion of the ore shoot.

Assays of Ore and Concentrates from Durgy Mine—Smelter Returns.

Date	Ore Pounds	Cu. Per cent	Ag. Ozs.	Au. Ozs.
1902				
Aug. 23	59,774	25.56	11.99	.01
" 23	73,081	13.85	7.49	.01
Sept. 12	12,433	13.41	5.9	.02
" 12	16,096	17.66	7.79	.13
" 12	13,757	32.60	13.83	.04
Oct. 21	60,299	27.82	11.55	.01
" 24	42,029	44.91	20.	.05
Nov. 15	54,799	39.55	17.37	.065
Dec. 1	37,765	35.63	15.20	.07
1903				
Jan. 8	46,727	32.25	14.61	.075
" 28	53,836	9.56	4.49	.01
Feb. 9	51,100	24.52	.....	.....
" 17	49,918	24.12	9.68	.02
Mar. 4	56,992	31.64	13.23	.075
" 19	45,400	15.22	6.34	.....
" 26	54,277	29.82	11.97	.055
Apr. 24	53,757	27.20	12.06	.07
May 9	52,662	26.49	11.81	.08
" 9	31,353	23.74	10.21	.03
" 23	27,151	27.52	12.11	.07
June 4	56,241	25.73	11.30	.055
" 20	55,778	23.67	10.44	.105
July 13	21,936	24.79	11.25	.05
" 13	32,012	24.19	11.03	.05
" 24	52,597	20.37	9.69	.045
Aug. 17	54,985	21.19	10.	.045
Sept. 12	59,125	21.25	9.55	.05
" 22	46,524	20.33	9.33	.07
Oct. 8	58,144	24.04	10.92	.045
1904				
May 5	49,401	10.82	4.17	.015
" 18	44,011	10.21	4.14	.02
June 27	39,806	12.09	n. d.	n. d.
July 20	43,712	9.07	"	"
1905				
Apr. 11	24,616	19.98	"	"
" 17	31,406	41.19	"	"
May 8	49,945	38.16	"	"
" 27	32,850	18.44	"	"
" 27	22,770	37.03	"	"
June 24	51,804	39.27	"	"
July 28	29,969	13.02	"	"
" 28	23,932	38.9	"	"
Aug. 2	60,625	9.45	"	"
Sept. 14	77,166	35.49	"	"
" 14	43,723	11.14	"	"

In this mine as in all other mines of the district the values are not evenly distributed linearly throughout the vein, but occur in certain places in it as definite ore shoots. Thus far there have been three such shoots discovered in this vein, two at the main workings, and one at a small pit near where the wagon road crosses the vein about 1,000 feet south of the main shaft. Only one ore shoot, that at the main shaft, has been developed to any important extent. It is nearly 500 feet in length and extends from the surface to the deepest workings of the mine. The work thus far done will not warrant any statement as to its pitch. The small stopes on the 155- and 335-foot levels, respectively, seem to indicate a second and probably smaller ore shoot, but the work done will not justify any very definite conclusions and this may be part of the main ore shoot. Such data as are available indicate an ore shoot at the pit near the roadside about 1,000 feet south of the main shaft. The quartz and other vein matter in the dump at this pit contain good showings of the green carbonate, and a few specimens contain more or less of the sulphides, largely chalcocite. Supporting this surmise is the fact that in the heading of the 335-foot level south, carefully collected samples across the entire vein show a little over 2 per cent copper and 1.62 ounces of silver per ton. The vein is strong in this territory and all indications point to the probability of another ore shoot.

Production.—There were no means of ascertaining the total production of the Durgy mine. It has, however, been one of the largest producers of the district. It is stated in an article by L. N. White^a that in 1901 there were on the dump and blocked out in the mine ready for stoping about 20,000 tons of ore. The mine was in operation the greater part of the time between 1901 and 1904, when J. Parke Channing made a commercial report on it. It is believed that the greater part of this ore was stoped out during the interval between these dates. In his report Mr. Channing said:

“I estimate that there is contained in the mine ready for stoping about 48,000 tons of ore containing 2 per cent copper and 0.9 ounce silver per ton.”

Between the date of Channing's report, 1905 and 1911, all the ore that was blocked out ready for stoping at the time of the examination was broken and hoisted, and a considerable amount of new work including stoping was done.

^a Mining and Metallurgy, Vol. 24, 1901, pp. 635-639.

Future of the mine.—As the Durgy mine stands to-day it is little better than a partially developed prospect. It is true that large bodies of good ore have been taken out, but development was not kept ahead of mining and as a result there is at present very little ore actually in sight. The future of the mine, therefore, depends upon the amount and grade of ore that further development will open up. Taking all things into consideration—the amount and grade of ore produced, the strong and persistent vein, the well-mineralized ore shoot which has been worked from the surface to the 335-foot level, and the two other probable ore shoots which have not been developed—it is believed that further prospecting and development work would certainly be advisable, and that it can be undertaken with a basis for a hope of rehabilitating the mine by locating valuable ore bodies.

In regard to future production from the Durgy mine Channing says:

“From a series of calculations and from an inspection of the maps, I am of the opinion that the average grade of ore to be expected from the Durgy mine will contain 2 per cent of copper and .09 ounce of silver per ton, and will contain 70 per cent excess silica. I figure that the cost of mining, including development, which I have estimated at 35 cents, will amount to one dollar and seventy-five cents per ton of ore mined and shipped.

“I am of the opinion that, from its present development, the mine can easily produce 30,000 tons of ore per annum. The vein is well defined and persistent and I believe will hold out in depth. In fact, in veins of this character I think that the better measure of their value is their capacity for production rather than the exact number of tons of ore which may be developed and in sight in the mine, this latter being entirely due to the caprice of the particular owner or manager.”

There are a few items that ought to be borne in mind when considering the question of future profitable operation of this mine. They are, that the ore occurs in definite ore shoots, and that while certain portions of the shoot may contain high-grade ore, by far the greater part of the ore is low grade, probably carrying little over 2 per cent of copper, and that upon the ability to handle this milling ore satisfactorily depends the success of the operations. It will, therefore, be necessary to handle large quantities of ore and to make a high saving of the values in the mill. Further suggestions and data on this subject are given in the chapter on concentration of the ores.

DUKE MINE.

General statement.—The southernmost mine in the district is about 15 miles southwest of Virgilina and is known as the Duke mine (formerly the Tingen mine). These prospects were opened and actively worked at the time of the copper excitement in the district during the late nineties. The rock is the normal greenstone schist of the district, possibly a little more "slaty" in appearance than the usual rock. There is much epidotization and some of the rock shows the purplish color so characteristic of these schists.

Geologic relations.—There are a number of veins on this property, all of which show traces of copper. The greater number of the veins appear to follow the schists in dip and strike, but some of them clearly have a more northerly trend than the schistosity of the country rock. There appear to be the normal irregularities as to width, and pinches and swells both horizontally and vertically.

Two shafts have been sunk beyond the pit stage. These are the main or Hicks shaft, which is about 280 feet deep, and shaft No. 3, about 225 feet deep. From the Hicks shaft two levels, one at 100 feet the other at 267 feet, have been broken off. The 100-foot level has been driven in the vein about 200 feet to the northeast and about 50 feet to the southwest from the shaft. The 267-foot level has been driven in the vein about 60 feet to the northeast. No stoping of any consequence has been done. From the 267-foot level cross-cuts have been driven each way at right angles to the vein, the northwest being 240 feet long and the southeast about 120 feet. It is reported that the northwest cross-cut intersected at a distance of about 85 feet from the shaft a narrow vein carrying high values in both copper and silver, and some gold, and at a distance of about 235 feet another similar vein was found. No development work was done on either vein. Only one vein was intersected by the southeast cross-cut, this was about 80 feet from the shaft. The main vein is the typical quartz vein of the district, about 4 feet wide, but only slightly mineralized. It is said that the shaft showed good values for the first 80 feet, but that below this point the vein became lean with rich spots here and there. In its widest part this vein is about 8 feet.

Shaft No. 3 is in a narrow but well-mineralized vein, said to vary from 18 inches to 4 feet. Only one level, the 100-foot level, has been driven from this shaft. This has been driven in the vein 120 feet to the northeast and about 60 feet to the southwest. Below this level the shaft has been sunk

125 feet. From the northeast drift a stope about 70 by 80 feet has been worked out, and from the southeast drift the ore from a similar stope about 20 by 40 feet has been broken out and hoisted. The workings were not accessible for study at the time of the examination but from reports, and judging from the character of the ore and other material on the dump, the shaft must have been sunk in a small but well-mineralized ore shoot. The gangue minerals are similar in both shafts and consist of quartz, epidote, calcite, chlorite, and a small amount of hematite. The ore minerals are also similar and are bornite, chalcocite, malachite, azurite, and a little cuprite, with a few specks of chalcopyrite here and there. The bornite and chalcocite show the microscopic intergrowths typical of the ores of the Virgilina district, and are believed to be hypogene or primary minerals and contemporaneous in development.

Future of the mine.—It is believed, that, while the development work has not been very extensive, enough has been done to justify a statement in regard to the future of the mine. At least two ore shoots have been proven to a greater or less extent, one at the Hicks shaft and the other at shaft No. 3. These may be expected to continue with depth allowing, of course, for variations in value. It may be expected that the veins intersected in cross-cutting from the Hicks shaft will develop values, but more work must be done in order to prove them. The mine appears to be in fairly good condition, and, taking everything into consideration, would certainly be regarded as a favorable prospect in which more development work ought to be done. The property is said to belong to Mr. Brodie Duke, of Durham, N. C.

PROSPECTS AND PARTIALLY DEVELOPED MINES.

NORTHEAST SHAFT.

The opening on the so-called "Durgy" vein, known as the northeast shaft, is located about 1,500 feet northeast of the main shaft of the Durgy vein. The shaft was filled with water and, therefore, not accessible at the time of the field investigations, but there was, however, a considerable quantity of high-grade ore, consisting almost wholly of chalcocite, in a pile near the shaft. Judging from a small outcrop near the shaft and from such data as were available, this vein is narrow, probably not more than 3 feet in width, but well defined, and can be traced for over one-half mile by quartz débris on the surface. It is parallel to the main vein in strike, thus

cutting the schistosity of the country rock at angles varying from 15 to 20 degrees. The shaft is said to have been sunk to a depth of 100 feet, and from the bottom a drift has been broken off, but very little stoping has been done.

The ore is nearly pure chalcocite, only a very little bornite having been noticed, in a gangue predominantly of quartz with small amounts of calcite, epidote, chlorite, and inclusions of the country rock. There is here considerable evidence that some of the included schist fragments have been in part replaced by quartz. The indications are that the chalcocite is largely supergene and secondary, having replaced bornite, and it is probable that with depth the ore will become similar to that of the main shaft. But little can be said as to the value of the ore or the extent of the ore shoot. However, it is certain that the shaft is located in an ore shoot of considerable promise.

THOMAS MINE.

The Thomas mine was opened about the time the first development work was done on the Holloway mine. It was thought at that time that the two openings were on the same vein, but, so far as the writer could determine, they are on separate and distinct veins. The Holloway vein has a trend of approximately north 15 degrees west, while, so far as could be determined, the Thomas vein has a northeast trend. Furthermore the location of the Thomas mine with respect to the Holloway renders it all but impossible for the two to be on the same vein.

The early work in the place was done by W. T. Harris and Henry Hyde. Later the property was sold to Whitney and Stevenson, a Pittsburgh firm. At the time of the field work the shaft had partially caved and was filled with water. Very little could be learned as to richness and general conditions of the vein, except what could be surmised from a study of the dump. It appears that the vein where opened was not strongly mineralized and that very little ore was produced. Careful search of the dump was made for ore, but not a single specimen could be found, due, perhaps, to the care with which the operators separated the ore from the waste material. It is stated that a few tons of ore were produced and shipped.

Two interesting items were noted in regard to the material from this prospect: The decidedly porphyritic character of the rock, and the numerous inclusions of fragments and plates of country rock within the white quartz of the vein. The country rock at this place appears to be the most nearly

typical porphyritic andesite found in the district. Indeed, it was from a study of material from this place that the true nature of the rock was first recognized by Watson and Weed. The inclusion of plates and irregular fragments of country rock give certain portions of the vein the appearance of having been developed in the torn-apart or rifted schists. Some of the fragments are fairly fresh rock, others are largely changed into chlorite, while still others show evidence of partial replacement by quartz. Figure 16, taken from Weed's^a "Types of Copper Deposits in the Southern United States," illustrates these inclusions.

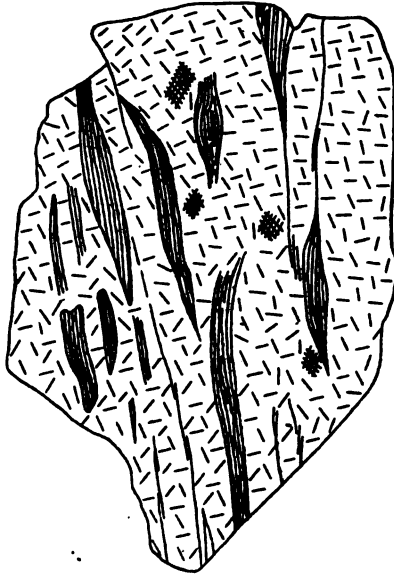


Fig. 16.—Sketch of a specimen from the Thomas vein, showing areas of schist enclosed in the white quartz. Specimen contains no ore. Three-fourths of natural size. (After W. H. Weed.)

CROSS-CUT MINE.

This so-called mine is only a shallow prospect shaft, probably 70 or 80 feet deep in a vein which outcrops rather strongly about one mile southwest of the main Durgy shaft, and which has a trend of north 30 degrees west. The schistosity of the country rock is about 30 degrees east of north, hence the name "Cross-cut" vein or mine. But little could be seen

^a Loc. cit., p. 463.

in the way of ore or vein matter, but there were very prominent stains of malachite in some of the material on what remained of the dump. The opening is in the bed of a small stream, dry during most of the year, but running freely during the rainy season, and nearly all the material taken out of the prospect has been washed away. It is reported that so far as the work went conditions were favorable. However, the vein is small, and about all that can be said in favor of the place is that by further work there is a possibility of finding a pay ore shoot.

A short distance southwest of the Cross-cut prospect are a number of quartz veins, usually small, which show copper stainings, and prospect pits have been made in a few places, but no development work has been done. One of these veins is parallel with the Cross-cut vein. On this vein, which is crossed by the public road and the small branch at the same place, a prospect shaft has been sunk, and a small amount of country rock and vein matter has been taken out. The material carries a small amount of ore, but nothing of much promise was seen.

Between the main shaft of the Durgy mine and a small stream about one-fourth mile northwest the public road crosses two prominent and well-defined quartz veins, each of which shows copper stainings. No development work, however, has been done.

BARNES MINE.

The Barnes mine, which in reality is only a prospect showing a small deposit of copper ore, is located on the east bank of Roanoke River, in Charlotte County, Virginia, about 8 miles from the junction of this river with Dan River, and about one mile south of Mass' Ferry.

It is not known when or by whom the prospect was first opened. There are rumors and traditions that the place was opened and that ore was extracted and reduced at the mine between 1700 and 1750. There is some evidence to support the statements that the place was worked years ago, but as to the date of the working nothing is known. The statements in regard to the early work as made to the writer by John K. Taylor, of Redoak, Va., who was present when the first work known to the present inhabitants of the region was done, are as follows: In 1880 or 1881, when some men were prospecting the quartz vein on which the mine is located, they opened up an old and unknown shaft, the opening of which had been walled in and covered with soil. This shaft was 57 feet deep, and from the bottom a drift 28 feet long led into a chamber or room 84 feet long and 16 feet wide and 18 feet high or deep, the floor of which was 35 feet below

the drift. In each end of this chamber there was a well or pit, one of which was 35 and the other 24 feet deep. In this chamber were found the remains of tools such as pick axes and shovels which had been used in the work. No dump nor any other surface indications of this work were visible, except a small amount of clinkers, cinders, or slag, many specimens of which show copper stainings.

A small amount of prospect work was done in 1881, but the place was soon abandoned. In 1898 the workings were again cleaned out and a little more prospecting done. The property is owned by James A. Barnes, of Redoak, Va.

The rock is the normal greenstone schist of the region, similar in all respects to that at the other mines. The strike and dip of the schistosity are north 30 degrees and 70 to 80 degrees to the southeast, respectively. The vein is predominantly of quartz, with epidote and calcite, varies from a few inches to 4 or 5 feet or more in width, and in strike and dip appears to follow the schistosity of the country rock. The ore consists of bornite and chalcocite, carries small values in silver and gold, and is apparently similar to the ore from the other mines in the district.

A short distance north of the Barnes shaft is another prospect shaft on the same vein known as the *MacLean shaft*. The vein is narrow, and at the shaft not strongly mineralized.

MCNENY MINE.

In the extreme northeastern part of the Virgilina district, a short distance southwest of Keysville, Va., there are a number of copper prospects which show rock, veins, ores, and general geologic conditions similar in all respects to those in the central and southern portions of the district. The most important and the best developed of these prospects, at the time the field work on this report was done, is known as the McNeny mine.

The McNeny mine is located on the Reese Fork of Twitty Creek about six miles southwest of Keysville and four miles east of the town of Drakes Branch. The openings, two in number, were made in a narrow quartz vein in the normal greenstone schists—altered basic volcanic tuff—similar in all respects to the rock at the High Hill, Holloway, Blue Wing, and other mines in the central portion of the district. The mine is on land belonging to a Mr. McNeny.

At the time of the field examinations for this report the mine was not in operation, the shaft was filled with water and consequently not accessible

for study. The statements here made are, therefore, based upon such data as could be obtained from an examination of the ore pile and dump, and from people who worked in the mine when it was in operation. The principal shaft is said to be about 150 feet deep, and to have been sunk in the vein. Little or no outcroppings of the vein were visible at or near the shaft, which was located in low ground near the creek. The vein is indicated on the surface both north and south of the shaft for a considerable distance by quartz débris. It appears to be narrow—from a few inches to four feet in width—and to present the usual irregularities such as pinches and swells and to follow the country rock in strike and dip.

The predominant gangue mineral is a hard, vitreous, white quartz, with a small amount of calcite, epidote, chlorite, and a little hematite. The ore minerals are bornite and chalcocite, similar to that from the other mines in relation and position in the vein, and in their relations to each other. The vein, while apparently pretty well mineralized—estimated to carry between 2 and 3 per cent copper—is so narrow that the mine from present development can not be regarded as anything more than a favorable prospect.

DANIEL'S MINE.

About one and one-half miles northeast of the McNeny mine, and probably on the same vein, are two prospect pits or shallow shafts known as the Daniel's mine. The vein is a well-defined quartz vein which shows considerable copper staining and in some of the material from the pits the sulphides still remain. The country rock, vein, ores, and their relation to the gangue, are similar in all respects to those of the largest mines in the district. The vein, however, is rather narrow, 2 to 4 feet, and with the present development the place can not be regarded as anything more than a prospect.

GILLIAM MINE.

The so-called Gilliam mine consists of a few prospect pits on a narrow but well-defined quartz vein parallel to and about one-fourth mile east of the Daniel vein. The conditions of vein, rock, and ores are similar to those at the Daniel's mine. There has not been sufficient development work to warrant any statement as to the permanent value of this prospect.

WILSON MINE.

A prospect pit in a quartz vein about three-fourths of a mile northeast of the Gilliam prospect is known as the Wilson mine. The vein is narrow,

and shows considerable copper staining, but from the small amount of work done nothing can be said as to what future work may develop. This prospect appears to be on the same vein as the Gilliam prospect, although it was not possible to trace it through from one to the other.

CRENSHAW MINE.

On Reese Fork of Twitty Creek, about a mile above the McNeny mine, are a few prospect pits known as the Crenshaw mine. These were sunk on a narrow, but fairly well-defined quartz vein, which follows the strike of the schists and which can be traced on the surface by quartz débris for about one-fourth mile. There is considerable copper staining at the prospect, which also shows some of the typical Virgilina sulphides, bornite and chalcocite. The small amount of work done will not justify any statements as to the permanent value of the place.

GROVE MINE.

About one-half mile northeast of the Wilson prospects are two or three prospect pits known as the Grove mine. The vein is narrow, but well defined and traceable on the surface for about one-fourth mile. The material taken out shows the usual type of ore of the district. Only a little work has been done and consequently nothing can be said as to its permanent value.^a

^a Since the field work on this report was completed the Grove mine has been developed to the stage where it is now the largest mine and the only producer in the northern portion of the Virgilina district. It has been developed by three shafts having depths of 60, 85, and 160 feet, respectively, distributed within a distance of 300 feet along the vein. The working or 85-foot shaft, which is an incline, has a total of 650 feet of drifts turned off from the shaft at the 60- and 85-foot levels. The 60-foot shaft, also an incline, located 160 feet north of the 85-foot shaft, is connected with the latter by the drift on the 60-foot level. The 160-foot shaft, a vertical shaft sunk in the hanging wall, is being sunk to catch the vein at a depth of 200 feet.

The vein is traced on the surface for a distance of about a quarter of a mile, strikes N. 35° E. and dips 75° S. E., and varies from 4.5 to 5.5 feet in width. So far as developments have extended the vein appears to increase in width with depth. In composition and structure the vein is of the normal Virgilina type. Bornite and chalcocite are the principal ore minerals. A little chalcopyrite and the oxidized or carbonate ores, malachite and azurite, occur.

The ore is hand picked, hauled by team a distance of 1,800 feet to a spur track from the Southern Railway, and shipped to the smelter at West Norfolk. Since October 1, 1916, the total shipment of ore will probably not exceed 2,500 tons net dry weight. (From notes taken by S. Philip Holt of the Virginia Geological Survey in a recent examination of the Grove mine.)

KAY MINE.

About one-fourth mile south of Dan River and about one mile below the mouth of Bannister River are three or four prospect pits and two shallow shafts which are known as the Kay mine. The place is owned by the Kay Mine Smelting Company, an organization incorporated under the laws of South Dakota, and having an office at Omega, Va. Only a small amount of work has been done and even this in an unsystematic manner. At the time of the field work, most of the openings were filled with water and inaccessible, and there was thus little opportunity to study the veins and ores.

The country rock is the mashed and altered "sandy tuff," or Aaron slate, that is, a rock made up of basic volcanic ash and tuff with which, at the time of its deposition, there was intermixed more or less terrigenous material consisting of grains and fragments of quartz, mud, and other land waste. This type of rock is fully described in the chapter on the detailed description of the rocks of the district. It is rare indeed in the Virgilina district that ore is found in this formation; in fact, the Kay mine is the only prospect, so far as known, that is located in it. Quartz veins are about as numerous in this rock as in the Virgilina greenstone, but for some reason they do not appear to have been mineralized as they were in the greenstone.

As far as could be determined the vein or veins at this mine are neither regular nor very well defined—certainly not like the typical veins of the district. It is true that there is a considerable amount of quartz and that the greater part of the ore occurs in it, but it appears to be somewhat irregularly developed and not to lie in the usual regular veins with well-marked walls. A considerable amount of mineralization has taken place in the country rock. In fact, it appears that a very important amount of the ore occurs outside of the quartz areas.

The ore is of the typical Virgilina type—that is, it is a mixture of bornite and chalcocite. In addition to the sulphides there is a considerable development of malachite, a small amount of azurite, and here and there a little cuprite. Assays of selected ore run from about 4 to about 30 per cent copper, from 1 and 1.5 to 7 ounces of silver, and as high as .05 ounce of gold per ton. There has not been enough development work to warrant any statement as to the probabilities of there being a large deposit of ore at this place. All that can be safely said is that the work thus far done shows up a small and irregular body of ore which, unless more can be developed, will be worthless. The place must be regarded merely as a prospect until sufficient work is done to either prove or disprove the size and value of the deposit.

CHAPPELL MINE.

The Chappell mine, or rather Chappell prospect, is located almost on the bank of Hyco River about two miles west of the High Hill mine. The development consists of two shafts, 87 and 55 feet deep, respectively, and about 125 feet of drifting. Shaft No. 1, nearest the river, is 55 feet deep and from it about 25 feet of drifts have been driven. Shaft No. 2, about 150 feet south of No. 1, is 87 feet deep and from it about 100 feet of drifts have been driven. They are located in a narrow, but fairly well-mineralized quartz vein, and are both probably on the same ore shoot. Both shafts were filled with water when the field investigations were made and hence inaccessible for study. There was, however, a considerable pile of fairly high-grade ore in a dump near the shafts, and it is reported that while the vein is narrow it is well mineralized. The country rock, vein, and ore are of the usual type of the district. There is also a prospect pit about 1,000 feet south of shaft No. 2. The material on the dump at this place shows more or less copper staining, but the work is not extensive enough to determine anything in regard to its value. This is also true of the deposit as a whole. The development work has not been extensive enough to either prove or disprove the property. The best that can be said for it is that it is a fairly favorable prospect.

PONTIAC MINE.

The Pontiac mine, formerly known as the "Tuck property," is located about 6 miles northwest of Virgilina and one and one-half miles west of Moffett post-office. It is reached by fair wagon roads, and is as accessible as the High Hill or Seaboard mines. There is no immediate water supply, but there is a small stream about one-half mile northwest of the property that by impounding could be made to furnish sufficient water for mining purposes, but would have to be pumped to the mine. The timber conditions are similar to those at the High Hill or Seaboard mines. There is an ample supply of both oak and pine for all mining purposes.

The veins of this mine were located sometime between 1895 and 1900. A little later the Pontiac Mining Company, the present owner, acquired the property and began active development work which continued until 1903, when all work was stopped and the shafts allowed to fill with water. No work has been done since that date and the property has been dismantled. Two shafts were operated, one on the eastern vein which appears to have a trend of 4 or 5 degrees west of north, and known as the Glasscock shaft, and one on a smaller vein about 1,000 feet west of the Glasscock,

known as the Tuck vein, which name was also given to the shaft. The two veins are very different in character and in the ore they produce. The Glasscock vein is irregular in width, strike, and dip, contains much epidote and in places only a moderate amount of quartz; in fact, it is reported that in places there was little vein matter of any kind unless the epidotized country rock in which the ores occurred could be regarded as the vein. The ore, too, is different from the usual ores of the district, in that chalcopyrite is present in considerable quantity, making up about one-third of the ore, the other two-thirds being bornite and chalcocite. The minerals of the gangue, named in order of their abundance, are: Epidote, quartz, chlorite, calcite, and hematite, which is present only in small amount. The ore minerals in the same order are: Chalcopyrite, bornite, chalcocite, malachite, azurite, covellite, and cuprite. Covellite, cuprite, the carbonates, and a part of the chalcocite in the upper portion of the vein are supergene minerals derived from the hypogene chalcopyrite, bornite, and chalcocite. The relations of chalcopyrite, bornite, and chalcocite make it reasonably certain that the three are to be regarded as hypogene or primary minerals, at least in part primary, so far as bornite and chalcocite are concerned. Many specimens of chalcopyrite showing alterations to chalcocite and covellite, and, in a few instances, doubtfully, bornite was noted on the dump, but it is believed that much of the bornite and chalcocite is hypogene and primary, and contemporaneous with the chalcopyrite. Many irregularities such as broken ground, mud seams, varying values, and different kinds of vein matter were noted in sinking the shaft. So far as there are data on which to base possible explanations of these phenomena, it is believed that they represent breaks and joints formed at the time the fissure in which the ore occurs was formed. The vein was for the most part developed in the fissure which crosses the strike of the schists, but when the fissure was formed the schists were more or less disturbed and torn apart, and, when the vein and ores were deposited, some of the depositions and alterations took place in the broken and rifted schist in the immediate vicinity of the fissure.

This shaft is 203 feet deep and one drift was broken off at 86 feet from the surface and driven about 50 feet to the south and 20 feet to the north. Conditions as regards ore are said to have been promising, but the vein, which varies from 2 to 6 feet in width, is reported not to have had well-defined walls and to have been difficult to follow.

There was no way of ascertaining the total amount of ore produced by this prospect. A pile of good ore representing several thousand pounds

was lying on a platform at the collar of the shaft, but how much more, if any, the mine produced is not known. It is not advisable to make any statements as to the future of this property until more exploratory work is done. As things now stand the place must be regarded simply as a fairly good prospect.

The Tuck shaft is about one-fourth of a mile southwest of the Glasscock shaft and is on a separate and distinct vein. The country rock is the normal greenstone schist, but contains less epidote than that at the Glasscock shaft. The vein is narrow, varies from a few inches to about 3 feet, and appears to follow the schists in dip and strike. The most abundant gangue mineral is quartz which makes up at least 80 per cent of the total vein. The ore and gangue minerals are similar to those at the Durgy mine and their relations to each other are typical of the district. The shaft was filled with water at the time of the examination, but, judging from the ore pile and the dump, the vein while narrow seems to have been well mineralized where opened by the shaft. Until more work is done this mine, like the Glasscock, must be regarded only as a fair prospect.

PANDORA MINE.

About 6 miles north of Virgilina and about 1 mile south of Moffett post-office is a shallow prospect shaft known as the Pandora mine. No work has been done at the place for a number of years. At the time the field work was being done the shaft was filled with water, and about all the data available as to the character of the vein and the ore were a few conflicting stories told by people in the vicinity and such inferences as could be drawn from examining a small amount of material on the surface at the shaft. The rock is the ordinary greenstone schist of the district somewhat more epidotized and not quite so highly schistose as usual. The ore, a small pile of which remained at the place, consisted of bornite and chalcocite with small amounts of the carbonates, and a little cuprite occurring in both epidotized country rock and quartz. A small amount of well-crystallized plagioclase feldspar, apparently albite, was noted in some specimens as a gangue mineral associated with the ore in quartz. So far as could be determined it appears that there is no regular and well-defined vein. The shafts seem to have been sunk in epidotized and somewhat mineralized area of the country rock. Until further development work is done the place must be regarded as a prospect of doubtful value.

MORONG MINE.

The so-called "Mother lode" mine of J. G. Morong is located about three and one-half miles due north of Virgilina. The shaft which is reported to be about 150 feet deep is located on a strong and well-defined quartz vein of the usual Virgilina type, which can be traced in the surface by actual outcrop and quartz débris for more than a mile. So far as could be determined from an examination of the material on the dump and from reports of men who were familiar with the place when the work was in progress, it is believed that no ore of commercial value was found. At least there is no evidence in the material now on the surface at the shaft of any such ore. The vein shows copper stainings in a number of places, and it may be that further development work would expose more favorable conditions, but, until such work is done, the place must be regarded as merely a prospect of very doubtful value.

BAYNHAM MINE.

The Baynham prospect or mine as it is called is located about 8 miles north and a short distance east of Virgilina. It consists of a dilapidated and partially caved shaft around the collar of which is a small dump consisting of schistose greenstone—the usual country rock—and a small amount of vein material, quartz, epidote, chlorite, etc., some specimens of which carry a little ore of the usual Virgilina type. The place has long since been abandoned and no data, other than that obtainable from the dump, were available as to the conditions of vein and ore. It is, therefore, regarded as a prospect of doubtful value.

ANACONDA MINE.

The Anaconda mine is located about one and one-half miles north of Virgilina on the east side of the public road, near the colored schoolhouse. It has not been operated for a number of years, and at the time of the field examination for this report was filled with water and not accessible for study. Very little authentic information in regard to it could be obtained from the people in the district, but the consensus of such data as could be obtained indicates that the shaft was sunk on a small but high-grade shoot of ore. The ore taken out was shipped and the greater part of the waste or barren rock hoisted has been hauled away for use in road building. However, such material as remained indicated that the mine had produced some good ore. Weed,^a in his report on the Virgilina district, says of this mine:

^a Loc. cit., p. 464.

"The ore is a mixture of glance and gray copper in quartz. The dump shows bright green schist largely impregnated with epidote. Some seven carloads [of ore] have been shipped from this mine, which varied from 3 per cent of copper in the first carload to 12 per cent in the last five carloads shipped. . . . The vein can not be said to have had a very extensive trial, and the ore thus far extracted has come from but one shoot."

THE CORNFIELD PROPERTY.

Situated in the southeast part of the Virgilina town site are two or three prospect shafts belonging to the William M. Pannebaker estate and known as the Cornfield Property. They were opened a number of years ago when mining was at its height in the district, but for some reason were soon abandoned and were not reopened until in the late fall of 1915. The shafts are only a short distance apart and are in the typical Virgilina greenstone, but the ore in each shaft is decidedly different from that in the others. They are designated "Cornfield No. 1," "Cornfield No. 2," and "Native shaft." The ores from the respective openings are so different that each will be described separately.

Cornfield No. 1 shaft when cleaned out was found to be about 55 feet deep and about 6 by 6 feet in the clear, and enlarged to about 9 feet at the bottom. The ore, consisting largely of chalcocite with only a small amount of bornite, occurs in a gangue of quartz, calcite, and a little epidote and chlorite, and in the country rock. There is, so far as the development has progressed, no well-defined vein, although there is a decided tendency for the ore to be segregated in different places in the mineralized portions of the rock. The writer did not have an opportunity of seeing the prospect after it was reopened, but, judging from data and specimens of the ores and rock which were kindly furnished him by the owners, it appears that this is certainly one of the promising prospects of the district and that it ought by all means to be given the attention which it deserves. In the notes furnished by the owners of the property it is stated that the whole width of the shaft, 9 feet, is more or less mineralized—all good milling ore, with a streak of chalcocite and bornite nearly four inches wide in one place.

The ores from this prospect are of more than ordinary interest in that they contain some of the finest examples of graphic or crystallographic intergrowths of bornite and chalcocite that were found in the district. These are described in detail and photomicrographs of them are shown in the chapter on the origin of the ores, and the descriptions need not be repeated here. The evidence afforded by these ores seems to the

writer to indicate very clearly that there are two generations of chalcocite—one of hypogene origin and contemporaneous with the bornite, and one of supergene origin and younger than the hypogene sulphides in which it occurs. Only the normal and usual minerals were found in these ores.

Cornfield No. 2 shaft is located about 400 feet east of No. 1 and in the same type of rock, but the ores are different in that they contain in addition to the usual bornite and chalcocite a large amount of chalcopyrite and an appreciable amount of pyrite which in the Virgilina district is an exceedingly rare mineral. This shaft was sunk entirely within a mineralized area of the country rock. While the ores thus far found in this prospect are not so promising as in the other shaft they are certainly worthy of further exploration. The ore minerals are chalcopyrite, bornite, chalcocite, malachite, azurite, klaprothite(?), pyrite, argentite, native copper, and cuprite. There are apparently two generations of both chalcopyrite and chalcocite, one of hypogene origin and one of supergene origin, and therefore younger than the hypogene mineralization. These relationships are discussed and illustrated in the chapter on the origin of the ores, and the discussions need not be repeated here further than to state that fine examples of the alteration of bornite to chalcopyrite were found.

The "Native shaft" is located in the southern part of the town site only a few hundred yards south of the Baptist church and a short distance east of the wagon road leading south from the town. This shaft is in the northern portion of an epidotized and mineralized belt of the Virgilina greenstone of varying width and extending southwestward along the strike of the rocks for about two miles, in which the ore, consisting of native copper, cuprite, and the carbonates, occurs for the most part in silicified and epidotized portions of the greenstone instead of in definite fissure veins as is usual in the Virgilina district. These deposits, if not exactly like Weed's^{*} Catoctin type of copper deposits, are very much like them. In fact, Weed himself places them in the Catoctin class. This subject is discussed in detail in the chapter on the detailed description of the ores.

The ore in the "Native shaft" consists of native copper, cuprite, and the carbonates in a gangue of epidote and quartz, the copper occurring for the most part in the quartz, but to a less extent in the country rock and in the epidote. There is no well-defined vein in the usual sense of the term, and the ore is found as granular and crystalline metallic copper in irregular

^{*} Weed, Walter H.: Types of copper deposits in the Southern United States. Trans., Am. Inst. Min. Eng., Vol. 30, 1900, pp. 498-504.

silicified and epidotized areas of the country rock and in short narrow quartz veinlets. The cuprite and the carbonates which are regarded as alteration products from the copper are disseminated through the country rock in the vicinity of the deposits. It is also probable that a part of the metallic copper occurs in the same manner, but, if it does, it was not discovered during the field work upon which this report is based. At the time of the field work this shaft was filled with water and not accessible for study. Very little of the ore which had been taken out was available for study, but such specimens as could be found consisted of native copper in quartz and epidote, together with cuprite and the carbonates as oxidation products. The shaft is reported to be about 60 feet deep and to have been sunk through ore. It is also said that a good part of the ore taken out in sinking was shipped to the smelter as high-grade ore. The shaft was cleaned out in the late fall of 1915, and the owners state that both quartz and epidote carry the ore which consists of the minerals just mentioned, and that there is no regular and well-defined vein, but that the quartz and epidote areas and veinlets which carry the ore are irregular in size and occurrence. This is one of the most promising of all the native copper deposits in the district, even though it has not been developed beyond the stage of a mere prospect. In the immediate vicinity of this shaft there are a number of silicified and epidotized areas of the greenstone which show more or less mineralization. On this account it would seem that this is as good a place as could be found in the whole district in which to try out, by well-directed development, the native copper deposits.

PANNEBAKER PROSPECTS.

About one-half mile south of old Blue Wing post-office, and a short distance west of the road and on the line between Person and Granville Counties, North Carolina, W. M. Pannebaker opened in the summer of 1907 a number of prospect pits in some epidotized outcrops of country rock containing irregular areas and stringers of quartz, which showed copper staining. In some places native copper and cuprite occurred with the malachite within a few feet from the surface, and in some of the pits considerable areas of well-mineralized rock were found. No sulphide minerals were noted. The primary mineral appears to have been native copper which was disseminated through the country rock, largely as thin plates in the planes of schistosity and as irregular grains and elongated areas in the quartz and epidote. The cuprite and the carbonate were derived from the native copper by oxidation. So far as could be determined the native

copper occurs in zones or areas in the country rock rather than in definite, well-defined quartz veins, and while the mineralization is extensive no deposits rich enough to mine have been opened. It is impossible to make, with any degree of certainty, any predictions as to the future of these deposits of native copper. It is certain that in many places the metal is widely disseminated through the rock, but, until further exploratory work is done, all such occurrences must necessarily be regarded as prospects of unproved value.

Native copper occurs in two other prospect pits, one only a short distance southwest of those just described, and the other at the roadside about 1 mile south of the Thomas mine. In both of these places the country rock is amygdaloidal and native copper and cuprite occur in the amygdules. Otherwise the conditions are similar to those at the Pannebaker prospects. Neither prospect developed a promising ore body. These deposits are also of the Catoclin type.

ANNIE MAUD PROSPECT.

About one-half mile south of Old Blue Wing post-office and a short distance east of the county road is a small prospect which is said to have produced some promising ore of the Holloway type, that is, the ore is largely chalcocite in a gangue in which quartz is subordinate to epidote. This shallow pit is known as the Annie Maud mine and is owned by the Wm. M. Pannebaker estate. So far as could be determined, the vein, as it is exposed in the prospect, is narrow, but it appears to be rather persistent and has been traced by quartz debris on the surface for considerable distances both northeast and southwest of the prospect. In fact, two other openings have been made in what, so far as could be determined, is the same vein. One of these, known as the Fourth of July mine, is located about one-fourth mile northeast of, and the other, an unnamed prospect pit, is about the same distance southwest of, the Annie Maud opening. The work thus far done is not sufficient to either prove or disprove the value of the prospect.

ENGLE PROSPECT.

The shallow pits and shafts about 1 mile northeast of the Gillis mine are known as the Engle mine. The work was done in a small but fairly well defined and narrow quartz vein which appears to be an extension of the Gillis vein. Considerable copper-stained quartz was exposed and a small amount of the usual sulphides, chalcocite and bornite, was found, but nothing of commercial value was developed.

GILLIS MINE.

The copper ores at the Gillis mine were discovered and the mine opened in 1852 or 1853. It is, therefore, one of the earliest worked copper deposits in the United States. It was examined by Ebenezer Emmons, State Geologist of North Carolina in 1854, and in his "Geology of the Midland Counties of North Carolina"^a he described the mine and stated that two shafts had been sunk to a depth of 80 feet, the south one showing 5 feet of vein and the north one 18 inches. He also noted that the expected change of chalcocite to chalcopyrite with depth did not occur in this mine. The vein does not present a prominent outcrop and appears to be narrow—about 3 feet wide on the average. It is difficult to trace on the surface, but appears to trend 10 degrees east of north and to dip about 70 degrees to the southeast. The rock is the normal Virgilina greenstone. The vein is composed largely of quartz, but contains appreciable amounts of calcite, epidote, chlorite, and a little hematite. The ore minerals are bornite, chalcocite, malachite, azurite, chrysocolla, tenorite(?), and cuprite. Emmons states that "vitreous copper" (chalcocite) occurred in a continuous belt 2 to 4 inches wide nearly pure. The mine has been closed for years and no data further than those given were available.

COPPER KING MINE.

A prospect shaft about 100 feet deep, known as the Copper King mine, is located about three and one-half miles southwest of Virgilina. There is apparently no well-defined vein, and the ore occurs in an epidotized portion of the country rock in which more or less quartz has been deposited in irregular areas or masses and in lenses and stringers. Aside from the excessive epidotization, the rock is the normal Virgilina greenstone. The gangue minerals are epidote, quartz, calcite, chlorite, plagioclase (probably albite), and a little hematite. The ore minerals are bornite, chalcocite, klaprothite, malachite, azurite, and cuprite, which in some instances occurs in the form of the so-called "plush copper ore" or chalcotrichite. The sulphides are intimately associated with all the gangue minerals. One specimen was found in which well-terminated albite crystals nearly an inch long and more than one-fourth inch in thickness were embedded in massive sulphides. The sulphide masses are always composed of an intimate intergrowth of bornite and chalcocite.

^a Emmons, Ebenezer: *Geology of the Midland counties of North Carolina*; 1856, pp. 344-346.

At the time of the field work there was a small body of good ore in a short drift which had been started from the bottom of the shaft, and there were a few thousand pounds of high-grade ore on a platform at the collar of the shaft. As conditions were at the time of the examination, there had not been enough development work done to warrant any surmise as to the future of the mine, and until such work is done the place must be regarded as a promising though unproved prospect. It belongs to J. H. Morong, of Virginia, Va.

COPPER WORLD MINE.

The Copper World mine is about one and one-fourth miles southwest of the Gillis mine and apparently on the strike of the Gillis vein—at least if the strike of the Gillis vein be produced along its regular trend southwestward it would reach the Copper World shaft. The rock is the normal green and purplish schist of the district. The vein does not outcrop, but judging from material on the dump it is the normal type of vein of the district, that is, white quartz with epidote, calcite, and chlorite. The ore is an intimate mixture of bornite and chalcocite with oxidized minerals near the surface. The only reliable information available in regard to this mine is by Weed,* who says:

"The Copper World was first opened in 1882. The present owner, Colonel Stiff, has sunk a shaft, 60 feet deep, with drifts at 30 and 60 feet. It is equipped with a small steam hoist and well timbered. The vein shows the usual white quartz with some epidote, encased in gray and purple schist. But one ore shoot has been crossed, from which 8 to 10 tons of high-grade glance ore has been stoped and shipped."

FOURTH OF JULY MINE.

A prospect shaft about two miles south of Virginia is known as the Fourth of July mine. Just why it is called a mine or why the shaft was sunk was not made clear from an examination of the material on the dump, which consists of normal greenstone schist with a few bunches of quartz here and there which in places show a slight amount of copper staining. So far as it was possible to determine there is no vein at the place.

ARRINGDALE MINE.

A few prospect shafts and pits were sunk a number of years ago on some fairly well-defined quartz veins about two and one-half miles northwest of the Durgy mine. These are known as the Arringdale mine. The work was soon abandoned, and, judging from the material in the various

* Loc. cit., p. 463.

dumps, with most excellent reasons. It is true that some of the material shows a slight amount of copper staining, but certainly not sufficient to warrant one in sinking a shaft.

LITTLEJOHN MINE.

About one-fourth mile west of the Seaboard vein are a number of closely spaced veins, some of which show considerable copper staining in the outcrop. The property including these veins was recently purchased by the Littlejohn Copper Company, of New York, and in one of the most promising of the veins three prospect shafts were started. These are all shallow, the deepest one being about 100 feet in depth, but they each show a narrow well-defined vein with considerable mineralization, the ore consisting largely of chalcocite with only a very little bornite. No assays of the material taken out were available, but from the general appearance of the vein it seems that further prospecting would certainly be justified. At least nine veins showing copper stainings, outcrop on the property owned by this company, and the most prominent of these veins are traceable by quartz and epidote débris as well as outcrops on the surface for considerable distances, in one instance at least two miles. They are, however, for the most part narrow and of doubtful value. As far as could be determined their strike appears to be parallel with that of the schistosity of the country rock.

ESTHER MAY PROSPECT.

In the Seaboard vein where it is crossed by the county road about one-fourth mile north of the Seaboard mine is a small prospect pit known as the Esther May mine. The pit is only a few feet deep, certainly not deep enough to either prove or disprove the property. The material on the dump shows a small amount of ore similar in all respects to the Seaboard ore and the prospect so far as could be determined is on the main Seaboard vein.

WALL MINE.

About three-fourths of a mile north of the Seaboard mine are two or three prospects known as the Wall mine. The country rock at these places is the tuffaceous phase of the Virgilina greenstone similar to that at the Seaboard mine. The vein, so far as could be determined, has a considerably more northerly strike than the schistosity of the country rock. At the time of the field investigation for this report this mine was not in operation. The shaft was filled with water and there was, therefore, no

opportunity for underground examinations. It is reported, however, that the vein is narrow, averaging not more than 2 feet in width, but that it is well mineralized. The material on the dump shows that the ore consists of bornite and chalcocite in a gangue composed dominantly of quartz, considerable epidote, and a small amount of calcite with a little chlorite. Only one opening of any importance was made in this vein. It is reported that the shaft was sunk through a depth of 135 feet and that a drift about 100 feet long was driven from the bottom of the shaft.

The ore from this mine when examined under the microscope proved to be the most interesting of the whole district in that it presented the best examples of crystallographic intergrowths of bornite and chalcocite that have ever been found.

A typical case of such intergrowth is illustrated in Plate XVII. At a magnification of 40 diameters these areas resemble very closely the intergrowths of quartz and feldspar in a micropegmatite, or the intergrowths of the constituents in certain alloys. At the highest magnification used, that of 575 diameters, this resemblance is even more pronounced. When an area of such intergrowth is etched deeply enough to bring out the cleavages distinctly the chalcocite is seen to be composed of numerous medium-sized individual grains, the cleavage lines of which could be seen to extend from one side of the grain to the other, interrupted here and there by the filaments of bornite. This type of texture is regarded as strong evidence that the two minerals crystallized at the same time. This subject is discussed in greater detail in the chapter on the genesis of the ores.

GOLD MINES AND PROSPECTS.

General statement.—All the copper ores of the Virgilina district carry small but variable values in gold. The usual values of the concentrates and ores in gold as shipped to the smelters vary from a mere trace up to 1.30 ounces per ton. It is also reported that "colors" of gold may be found in many stream beds and other places in the district. However, so far as was determined during the field investigations for this report, there is only one area included within the district as shown by the accompanying map (Pl. I) which shows the presence of gold in sufficient quantity to warrant prospecting for it. This is an area about 2 miles wide extending from about 2 miles to 6 miles northeast of Virgilina. The southern half of this area, which contains many irregular quartz veins and stringers, stands a little higher than the surrounding country and is known as Gill's Mountain.

It is said that nearly any stream in this area, by panning, will show from one to many colors of gold, some of which is fairly coarse. A number of prospect pits have been sunk and many cross-cuts made in the area, with the hope of locating valuable deposits. Many of these show gold, but it is nearly always present in too small amount to be of any commercial value. While many of these veins and stringers show pyrite and gold it is very seldom, indeed, that they show any of the copper-bearing sulphides. Of all the pits and cross-cuts in this territory only three show indications that might possibly warrant further prospecting. It also seems probable that these three are all on the same vein, at least in the same mineralized zone. These, beginning with the one farthest south, are: The Poole and Harris Prospect, the Red Bank Mine, and the Luce and Howard Mine.

POOLE AND HARRIS PROSPECT.

About one and one-half miles south of the Red Bank mine are a number of shallow pits and cross-cuts in a quartz vein which in places shows rather favorable pannings. Only very little surface work has been done and no assays are available nor other data that would afford any quantitative information. As conditions are, the place can not be regarded as more than an undeveloped prospect.

RED BANK MINE.

The Red Bank mine is located about four and one-half miles northeast of Virgilina, and about one-fourth of a mile north of the wagon road leading from Red Bank store to Hitesburg. It was the only gold mine in active operation at the time of the field work. In fact, it is the only gold mine thus far developed to any important extent in the whole region. The veins were discovered and active development was begun in 1903 by H. C. Crowell. Very soon after the discovery, W. T. Harris became associated with Mr. Crowell in the development work. These men carried on the work until 1905, when they sold the property to its present owners, the Virgilina Mining Company, with headquarters in Buffalo, N. Y. The surface plant consists of a small stamp mill, ore bins, crusher, air compressor, boiler, and engine all well housed. All the ore thus far taken out was handled by the stamp mill and amalgamating plates. Much of the gold has been proven to be very fine and consequently the slime loss has always been considerable. To avoid this the company purchased a cyaniding outfit, but for some reason did not install it.

The underground development consists of two shafts, one about 50 and the other about 200 feet deep, and about 650 feet of drifts. The first level at a depth of about 70 feet extends 370 feet south and 120 feet north of the shaft. The second level extends about 90 feet south and 100 feet north of the shaft. Considerable stoping has been done, but little or none of it extends below the 70-foot level. All drifting and development work has been confined to the one vein.

The country rock is the usual greenstone schist of the district. The green- and purplish-colored types of the rock are both present and its tuffaceous nature is plainly visible upon close examination. It appears that the rock is probably more highly schistose than at the other mines. The vein is of the fissure type and appears to follow the dip and strike of the schistosity of the rock in which it occurs. It varies in width from a few inches to 6 feet, averaging perhaps three and one-half feet. The walls are well defined and the vein is easily followed. Much silicified country rock is included in the vein and much of it has a decided reddish color resembling jasper, due probably to the development of hematite in the siliceous material.

It is said that the richest values were found in the reddish portions of the vein. The upper portion of the vein seems to carry only two metallic minerals, gold and hematite, but with depth a small amount of pyrite began to come in. The values are not evenly distributed throughout the vein, but they occur in a well-defined ore shoot, only one of which has been developed, although others of more or less promise are known to exist. Even in the ore shoot the values are "spotty" and in places the vein carries very little or no value. No properly made assays were available, and it is therefore not possible to make any statement in regard to average value of the ore per ton. However, it is reported that up to date (1912) the mine had produced a total of \$22,000 worth of gold.

It is not known why the mine has been allowed to lie idle so much—whether due to lack of suitable ore or to the management. H. C. Crowell, who is familiar with the workings, says that there is a good body of average grade ore in sight, but that much of the gold is too fine to be saved on amalgamating plates and that this fact is responsible for the idleness.

Not much can be said with any degree of certainty as to the future of the mine. Certainly some high-grade ore was taken out, but it is not known how much remains unbroken. Until more development work is done the place must be regarded as a favorable, but unproven, prospect.

LUCE AND HOWARD MINE.

A prospect on a hill about one-fourth of a mile northeast of the Red Bank mine and apparently on the same vein is known as the Luce and Howard mine. The metal sought was gold which occurred in small quantity in quartz veins and stringers in the schists. The place was not in operation at the time of the field examinations for this report and the workings were not accessible. So far as could be determined from examinations of material on the dump, conditions are somewhat similar to those at the Red Bank mine. Three shafts have been sunk to depths varying from 75 to 100 feet, but little or no stoping is said to have been done. A small stamp mill and concentrating machinery have been installed, but no data were available as to the success of the mill. It is reported that much of the gold is very fine and as a consequence very difficult to save by amalgamation.

UTILIZATION OF THE ORES.**GENERAL STATEMENT.**

There are three ways of utilizing the Virgilina ores: (1) Ship the run-of-mine ore, less such waste material as can be eliminated from a picking belt, direct to the smelter for use as converter linings or as a siliceous material for fluxing heavy sulphide ores or concentrates. (2) Concentrate the ores and ship the concentrates. (3) Extract the metals from the ores in a plant erected in the district for the purpose; such plant might consist of a smelter or be equipped for roasting the ores and concentrates and leaching the valuable metals from the roasted material.

SHIPMENT OF ORE WITHOUT MILLING.

The location of the district and the type of ore produced are favorable to the first-mentioned way of utilizing the ores, that is, ship the roughly picked ore direct to the smelter for use as siliceous material. The district is not far removed from a number of smelters, and, if reasonable freight rates can be obtained, the hand-picked ore, carrying from 4 to 8 per cent of copper and 70 per cent excess silica, could undoubtedly be shipped at a profit. The nearest smelter is the Virginia Smelting Company, at West Norfolk, Va., only 147 miles distant. This smelter at the time of the field work was treating large amounts of roasted pyritic copper ore, "spent pyrites," from Canadian points, and the management was more than anxious to have siliceous ores to serve as flux with the heavy iron ores.

Very reasonable freight rates were in force between Virgilina and Norfolk and if proper contracts could have been made which would have assured the smelter a steady and regular supply of siliceous ore, and, at the same time had assured the miner a steady and fair market for his ore, it is reasonably certain that the whole output of the district could have been disposed of to this smelter. In fact, the greater part of the output was handled by this smelter.

In case the Norfolk smelter could not handle the ores, the smelters in New Jersey and the Tennessee Copper Company's smelter at Copper Hill, Tenn., are within reach. They are farther away and the success of shipping to these markets would depend upon the kind of freight rates that could be obtained. All these smelters are buying silica for use as flux, and it is believed that by assuring the railroad of regular and large shipments of ore, the price for the excess silica in the ores would almost, if not quite, meet the transportation charges and thus enable the operator to deliver the actual copper ore to the smelter free of, or for a very small, freight charge. These smelters, especially the one at Copperhill, Tenn., have used many shipments of ore from the Virgilina district. Indeed, in 1909 and 1910, the Tennessee Copper Company did considerable exploratory work in the district for the purpose of ascertaining whether or not a sufficient supply of siliceous ores could be obtained for their smelter. The project failed, but it is said not from a lack of ore, but because of exorbitant prices demanded for property.

In order to sell Virgilina ores in this way to the best advantage it will be absolutely necessary for the district to be able to deliver steadily and regularly a reasonably large tonnage of fairly uniform ore. There is probably not a mine in the district, when operated as a single unit, that can meet such conditions, but if a number of the most promising mines and prospects would combine in marketing their ores the conditions could be met very easily. It seems perfectly evident that the only way to operate the mines on the basis of greatest profit to the individual owners is to consolidate them, at least so far as selling and shipping the ore is concerned.

MILLING THE ORES AND SHIPMENT OF CONCENTRATES

Sufficient experimental work, and actual milling of the Virgilina ores on a commercial basis, have been done to demonstrate beyond any question that they are readily amenable to concentration. This statement is made with full knowledge of the failure of both the High Hill and Person Consolidated mills to give satisfactory results. It is perfectly clear to any

one familiar with the construction, equipment, arrangement, and management of these mills, that the causes for failure lay within the mill and its management and not within the ores. Every mining engineer of any standing who has examined properties in the district has either strongly recommended concentration or remarked that the ores are favorable for concentration. The important minerals of ore and gangue together with the specific gravity of each are given in the following list:

<i>Ore Minerals</i>	<i>Specific Gravity</i>
Bornite	4.90 to 5.40
Chalcocite	5.50 to 5.80
Argentite*	7.20 to 7.36
Chalcopyrite ^b	4.10 to 4.30

<i>Gangue Minerals</i>	<i>Specific Gravity</i>
Quartz	2.65 to 2.66
Calcite	2.71
Epidote	3.25 to 3.50
Chlorite	Under 3.00
Average rock	About 3.00

It is seen that there is a difference in specific gravity of 1.7 between the average bornite, the lowest important ore mineral, and the average of epidote, the highest important gangue mineral. In good milling practice it is possible to separate without great difficulty minerals having a difference of little more than .5 in specific gravity. It is, therefore, clear that so far as the relative specific gravities of the gangue and ore minerals are concerned there is nothing to interfere with successful concentration.

There is, however, one feature that complicates the problem and one which must be seriously considered in any attempts to concentrate these ores. This is the brittleness of bornite and chalcocite, the principal ore minerals, and the toughness and hardness of epidote and the hardness of quartz, the principal gangue minerals. Consequently, there will be a strong tendency for the ore minerals to crush very finely and form a great deal of slime, which will be lost in the milling process unless careful measures are taken to save it. The best way to save slimes in ore dressing by gravity methods is not to make them; therefore in treating these ores every precaution must be taken to prevent the formation of slimes. In planning a method of treatment for these ores, this question must be given first and foremost consideration. Then, in spite of every precaution, a certain

* It is assumed that the silver in the ores occurs in the form of argentite.

^b Chalcopyrite occurs in appreciable quantities in only two mines or prospects in the district—the Glasscock shaft of the Pontiac mine, and the Cornfield No. 2 prospect.

amount of slimes will be formed, so that no process could be considered adequate which did not include apparatus for collecting and saving slimes. One of the fundamental principles of ore dressing is never to crush the ores any finer than is absolutely necessary to free the valuable minerals from the deleterious or worthless material. In applying this principle to the Virgilina ores there is both a fortunate and an unfortunate feature. The fortunate one is the fact that in most of the deposits the ores are pretty well bunched or segregated in fair-sized areas, and can be saved without exceedingly fine crushing. The unfortunate feature is the fact that this segregation was not carried to completion and as a consequence there is a great deal of vein through which the ore is finely disseminated and which therefore must be crushed very finely. Therefore, in devising a system of treatment means must be provided for taking out as much ore as possible without crushing and to crush only what is absolutely necessary and then not any finer than is absolutely necessary to free the values from the gangue. This makes it necessary, in order to treat any of these ores to the best advantage, to provide a picking belt which takes the ore from a rock breaker in which it is broken to about 2-inch size but no finer. From this belt three products will be obtained—a shipping ore, a milling ore, and much barren quartz and country rock. A picking belt is regarded as essential to any equipment for dressing these ores.

The mill equipment of the High Hill, Person Consolidated, and Seaboard mines has been described in the paragraphs relating to these mines and will not be repeated here. Of these mills only the Seaboard was a success. Before erecting this mill, A. W. Tucker, at that time manager of the Seaboard mine, carried out a great deal of experimental work on the ores, with the object of determining the best type of treatment for them. This is the only work of its kind thus far attempted with the ores from the district, and it seems best to quote briefly from Mr. Tucker's report of his work.

"The tests were made on ore from the Seaboard mine in the ore dressing laboratories of the Massachusetts Institute of Technology, Boston. The total amount of ore used was a trifle under two tons. It had been crushed at the mine to 2-inch size and all high-grade ore taken out. By high-grade ore is meant all ore running 10 per cent copper or over. This was done to take the place of a picking belt which is essential to any mill in the district. Much work was done on the ore for two purposes: First, to determine the fineness to which the ore must be crushed in order to produce the greatest percentage of saving in the simplest manner; and, second, to determine the adaptability of various machines to the concentration of this particular ore. Under such conditions it is readily seen that a negative result would

be nearly as valuable as a positive one. From the results obtained the proper mill to install can be determined easily, but the individual test or run has little value by itself. Three complete runs or tests were made. They are as follows:

"In the first test the ore was crushed and then reduced to 5-mesh by putting it through one set of rolls. This 5-mesh product was fed direct to a 3-compartment Harz jig, containing 12-mesh bottom screens and allowed to make its own bed. The hutch product was run in a one-spigot classifier which gave two products, heads and tails. The jig tails, jig middlings, and the classifier tails were mixed and run through a gravity stamp mill having a 14-mesh screen. The stamp mill pulp was classified and the various sizes run on Wilfley tables. The mud from the jig was added to that from the Wilfley tables and run on a Wilfley slime table. This test showed a total saving of 81.09 per cent of the total copper in the ore, distributed as follows: Jig, 48 per cent; Wilfley table, 27 per cent; Wilfley slime table, 6 per cent. The original ore assayed 2.78 per cent copper, hence the ratio of concentration was 14 to 1.

"The second test was one of graded crushing with rolls through 8 mesh. The material was classified in a 4-spigot classifier, Spigot No. 1 went to the jig, the middlings being run on gravity stamps having a 20-mesh screen. Spigots Nos. 2, 3, and 4 were treated in the usual manner on Wilfley tables, the overflow going to a Wilfley slime table. This test was made on ore assaying 3 per cent copper. The saving was 88.22 per cent of the copper and was distributed as follows: Jig, 52.61 per cent from treatment of material from spigots Nos. 2, 3, and 4; and overflow, 15.10 per cent; treatment of jig middlings, 20.51 per cent. In this test, however, all products assaying 10 per cent or over were called heads without further concentration and the ratio of concentration would therefore be low.

"In the third test the two-inch material as received from the mine was fed directly to gravity stamps having a 14-mesh screen. The pulp was classified and run on Wilfley tables; 79.30 per cent of the total copper content of the ore was saved as follows: Wilfley tables, heads, 60.54 per cent; round table, heads, 6.43 per cent; and Wilfley slime table, 12.33 per cent. The original ore assayed 2.80 per cent copper. The test showed the round table to be almost worthless as a machine to follow Wilfley tables. If these tables had been followed by a Wilfley slime table as in the other tests the extraction would probably have been higher.

"It was also found that the gold and silver values concentrate with the copper."

The mill at the Seaboard mine, which was built and operated by Mr. Tucker after he had completed the experimental work on the ores, was, so far as can be determined, very successful, but did not make as high a saving as was made in the experimental runs. The flow sheet on page 100 shows the equipment of this mill.

CONCENTRATION BY FLOTATION.

While flotation has not been tried on the Virginia ores, it has been practised with such great success throughout the world upon many ores far more difficult to treat than these that there is absolutely no doubt that, if given a fair trial, it will prove to be as successful here as elsewhere. In fact from the writer's knowledge of the subject he is certain that it is the most promising of all available methods of concentrating the Virginia ores. Its advantages over other methods of concentration for these ores are so evident that it really seems unnecessary to discuss them except in a general way. The most patent advantage is in the handling of slimes. The worst feature of all other methods of concentration is the difficulty of saving the slimes. The condition of the ore is such that in order to free the values from the gangue, it is necessary to crush it very finely and this can not be done without making a large amount of slimes. Because of this it is necessary in considering any method of concentration to include a method of treating the slimes. Flotation thus far is the only really successful method known of treating such material.

Another very important fact in regard to flotation is the flexibility of the process. It can be used alone or in combination with table concentration with equal facility. Thus, if it is desired to use ordinary gravity concentration for everything except slimes and to treat them by flotation, it can be done easily and economically. A flotation machine large enough to treat the slimes from a 50-ton mill will cost but little more than a slime table for the same purpose, and it will not require a great deal more operating power. It is also just as practicable and certainly more economical to arrange to do all the concentration by flotation as by ordinary methods, or by a combination of the two.

Finally the item of cost of installation and operation of a suitable concentrating plant is believed to be greatly in favor of flotation. The greatest expense is that of crushing machinery, and this has to be met in either case regardless of the method of concentration used.

It is not the intention of the writer to go into the question of flotation in detail. In fact, such a discussion would be out of place in a geological report. All he desires to do is to call the attention of the operator in the district to the importance of the subject and to suggest that it be given careful consideration.

SMELTING ORE IN THE DISTRICT.

The last of the three ways of treating the ores, smelting or extracting the metals from them in the district, is considered the least feasible of all. There are many reasons for this conclusion, among which may be mentioned the following: There is not only no readily accessible fuel supply but no supply of material suitable for flux. It would, in all probability, be less expensive to ship the ore or concentrates to a smelter than to pay transportation charges on fuel, material for flux, and general supplies. It does not appear probable that the district will ever produce large quantities of ore—probably not enough to supply a large metallurgical plant. Small copper smelters are usually not very satisfactory and they generally are more expensive to operate than large plants in proportion to the amount of metal produced.

It is realized that there is a possibility of treating these ores by hydro-metallurgical processes, and that such processes might eliminate certain of the obstacles in the way of smelting operations.

It is even true that a process for extracting the copper from the ore by acid leaching and recovering it by electrolytic precipitation was installed and operated a short time in 1907 at the High Hill mine. The process and results were kept secret, but it is well known that from a commercial standpoint the plant was a failure. The process so far as it could be learned consisted in giving the crushed ore a sulphating roast in a specially constructed reverberatory furnace, leaching the roasted ore with dilute sulphuric acid, and finally precipitating the copper electrolytically.

In considering any method of treating as well as mining the Virgilina ores the prime factor must be to keep expenses down to the minimum. The two methods just considered are of necessity expensive and on this account, if for no other reasons, are not considered feasible.

The first two ways mentioned of utilizing the ores, shipping the hand-picked ores to smelter or of milling the run-of-mine ore, less such waste as can be easily eliminated from a picking belt, are both considered feasible, and it is recommended that they be given careful consideration by any one contemplating operations in the Virgilina district.

SUMMARY.

Of the three methods of handling the Virgilina ores that have just been discussed, namely, shipping the hand-picked ore, concentrating the ore and shipping the concentrates, and reducing the ore to metal in the

district, the second one appears to the writer to be the most feasible. This is also the conclusion reached by most of the men who have at different times operated mines in the district, as well as it is the opinion of the best mining engineers who have written commercial reports on the district. Unless straight flotation be adopted a fairly complicated equipment will be required in the treatment of these ores, and in order to secure the greatest efficiency it will be necessary to handle as large quantities of ore as possible. A large mill will, therefore, be necessary. Taking into account the small size of the individual deposits, it appears that it would be little short of actual folly for each individual mine to erect a concentrating plant. The cost of erecting and operating the mill would be almost, if not quite, prohibitive. The writer believes that the most satisfactory as well as the most economical plan would be some scheme of coöperation between the different operators in the district whereby there could be erected a centrally located mill large enough to handle all the milling ores from all the mines. Such a mill could be located on Aaron's Creek near the railroad. Each mine could install and operate a picking belt so that it would be necessary to haul only the concentrating ore to the mill.

As regards transportation it seems probable since motor trucks have been developed to such a high degree of efficiency that they could be satisfactorily employed for the purpose.

It seems desirable before discontinuing this subject to quote a summarized statement of the recommendations given by Mr. H. A. Keller in a commercial report on the district a few years ago. This was written before flotation had been developed to such a high degree of efficiency, but it is still worthy of the most careful consideration by any one contemplating mining in the Virginia district.

"(1) The ore should be crushed at the shaft and the high-grade smelting ore saved and the waste eliminated from a picking belt before the ore goes to the mill.

"(2) The ore should be jigged as coarse as possible in order to avoid crushing or pulverizing the small bunches of pure minerals—thereby avoiding as much slime loss as possible.

"(3) The jig tailings must be recrushed and concentrated further.

"(4) Some satisfactory treatment must be provided for slimes."

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